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CITIZEN SCIENCE LAKE MONITORING: EXPLORING CHEMICALS OF EMERGING CONCERN MONITORING IN NEW YORK STATE

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by

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ABSTRACT

K. M. Fee. Citizen Science Lake Monitoring: Exploring CECs Monitoring in New York State. 136 pages, 9 tables, 20 figures, 2019. APA style guide used.

Citizen science, defined as voluntary public participation in scientific research, is a form of scientific exploration that has grown tremendously in recent years. Chemicals of emerging concern (CECs) are chemicals found in the environment which may pose risks to human and ecosystem health. This research project utilizes a survey to better understand the knowledge and awareness that citizen scientists associated with the Citizens Statewide Lake Assessment Program (CSLAP) in New York State have about CECs, as well as the motivations behind their current roles as citizen scientists. CSLAP monitors hold some knowledge of CECs, but many have knowledge gaps and would like to learn more about CECs, and participants are motivated by a number of factors, but primarily by their interest in the topic of water quality. Clarifying and disseminating information about CECs, integrating CECs research into citizen science programs, and understanding volunteers' motivations are some implications of this research.

Key Words: Citizen science, chemicals of emerging concern, CECs, water quality, knowledge, motivations

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CHAPTER 1: INTRODUCTION

Citizen science is an expanding form of research that can be utilized in many scientific communities to gather data, share knowledge, and influence policy and decision making (Lewandowski, Caldwell, Elmquist, & Oberhauser, 2017; McKinley et al., 2017; Vann-Sander, Clifton, & Harvey, 2016). The past few decades have seen a notable increase in the number of citizen science projects being implemented for multiple different scientific fields, and its ability to generate data sets that would otherwise be prohibitively expensive or wide-ranging for individual research groups to collect makes citizen science research an important tool for scientific research (McKinley et al., 2017; Storey, Wright-Stow, Kin, Davies-Colley, & Stott, 2016). Chemicals of emerging concern (CECs) are chemicals which have recently come to the attention of researchers and other professionals for their potential to threaten the health of humans and the environment (Elliott, Brigham, Kiesling, Schoenfuss, & Jorgenson, 2018; Hamza, Iorhemen, & Tay, 2016; Sharma et al., 2019). These chemicals are present in a variety of products, including household cleaners, cosmetics, medicines, and pesticides, and require much more research to fully understand their potential impacts and better inform future regulations.

This research aims to better understand the knowledge and awareness that water quality monitors have about CECs as well as what motivates individuals to become and remain involved with water quality monitoring and citizen science initiatives. By developing and implementing a survey, individuals from the Citizens Statewide Lake Assessment Program (CSLAP) in New York State were able to respond to various questions, which provided information regarding these objectives.

This thesis begins with an overview of both CECs and citizen science. An introduction to what CECs are as well as their sources, impacts, treatment processes, and some regulatory information is included. Following this, citizen science is discussed, which includes what citizen science is, the outcomes of citizen science research, the limitations and challenges associated with citizen science initiatives, the motivations behind citizen scientists' involvement, and a brief overview of some successful citizen science initiatives, both globally and domestically. Following this analysis are the survey methods, results, and the overall findings, conclusions, and implications of this research.

CHAPTER 2: REVIEW OF LITERATURE

CHEMICALS OF EMERGING CONCERN

Introduction

The term chemicals of emerging concern (CECs) refers to compounds, both naturally occurring as well as synthetic, that may pose risks to human health and the environment, and that have recently been discovered or were previously found in lesser concentrations that were not of concern at the time (Hamza et al., 2016; Kray & Wightman, 2018; Sauvé & Desrosiers, 2014). CECs have been released into air, soil, and water for as long as they have been in existence, and while some may degrade within a few days or weeks, others can persist in the environment for centuries before degrading through abiotic or biotic processes (Harris & Smith, 2016). These chemicals are referred to by many different names including contaminants of emerging concern, emerging substances of concern, compounds of emerging concern, and emerging contaminants, however the acronym 'CECs' is most commonly utilized in the literature to refer to these chemicals. CECs are released into the environment through a variety of pathways, and their distribution depends on a wide range of factors, including the substances' physiochemical properties such as water solubility, polarity, and vapor pressure, and the environmental conditions present, including pH and organic matter content (Nilsen et al., 2018). The widespread use of CECs as well as their interactions with environmental stressors, such as invasive species and land-use changes, make them challenging to study and understand, requiring interdisciplinary expertise from scientists in the fields of biology, ecology, chemistry, and toxicology (Nilsen et al., 2018).

CECs have been found in a variety of products including: pharmaceuticals, personal care products, artificial sweeteners, pesticides, surfactants, disinfection by-products, flame retardants, perfluorinated compounds, and nanomaterials (Hamza et al., 2016; Sauvé & Desrosiers, 2014; Sharma et al., 2019). CECs tend to persist in the environment at low concentrations, ranging from a few nanograms per liter to several micrograms per liter (Luo et al., 2014), and while these low concentrations make them extremely challenging to detect, the development of new and advanced technologies has allowed for a dramatic increase in the amount of CECs cataloged in recent years (Sharma et al., 2019). They have now been discovered in almost every aquatic environment in North America, Europe, Asia, and Africa (Hamza et al., 2016), and there is a high likelihood that they exist in all aquatic environments around the globe.

Sources of CECs

Pharmaceuticals and Personal Care Products

Many pharmaceuticals (PhACs) and personal care products (PCPs) contain CECs. PhACs are utilized by a substantial portion of the global population for human and animal health purposes and are released into the environment in large quantities following incomplete absorption and excretion from the body (Cizmas, Sharma, Gray, & McDonald, 2015). Some PhACs that contain CECs include certain antibiotics, antidepressants, antiepileptic drugs, nonsteroidal anti-inflammatory drugs, cytostatic drugs, illicit drugs, caffeine, and hormones (Cizmas et al., 2015; Gogoi et al., 2018; Hamza et al., 2016). CECs are also present in many PCPs, which are primarily used for health and beauty purposes. These are applied to the body of humans and animals and are expelled via showering, bathing, and cleaning (Birch, Drage, Thompson, Eaglesham, & Mueller, 2015). Some PCPs that contain CECs include certain cosmetics, fragrances, UV filters, disinfectants, insect repellants, and preservatives (Hamza et al., 2016; Montes-Grajales, Fennix-Agudelo, & Miranda-Castro, 2017). Many of these chemicals are synthetic, bioactive, and bioaccumulative (Montes-Grajales et al., 2017), and some chemicals within PhACs and PCPs have the ability to combine to produce synergistic toxicity (Cizmas et al., 2015). Public awareness of the impacts of PhACs and PCPs on aquatic environments and humans is growing, and governments around the world are taking action on many of these chemicals (Cizmas et al., 2015).

Artificial Sweeteners

Some artificial sweeteners (ASWs), which are primarily used in food and beverages but are also present in some PhACs and PCPs, are considered CECs and have been detected in groundwater, surface water, drinking water, and wastewater in the U.S., as well as waters of Switzerland, Germany, China, India, and other countries (Li et al., 2018; Mawhinney, Young, Vanderford, Borch, & Snyder, 2011; Sharma et al., 2019). Some prevalent ASWs that are CECs include aspartame, acesulfame potassium, cyclamate, saccharin, and sucralose (Li et al., 2018; Praveena, Cheema, & Guo, 2019), which can be found in the ingredients list of a substantial amount of consumer products. Eighty-five to ninety-five percent of sweeteners are excreted from the body after ingestion (Praveena et al., 2019) as they often cannot be absorbed or metabolized well by humans (Mawhinney et al., 2011), and ASWs' resistance to common wastewater treatment processes, as well as their high solubility and environmental stability, allow them to persist in waterbodies at large concentrations for long periods of time (Sharma et al., 2019). The effects of ASWs on the environment are not well known, but some studies have shown that they interfere with photosynthesis and carbon dioxide intake of plants (Praveena et al., 2019) and that some can induce heavy metal uptake in green algae, which can lead to larger scale food chain impacts (Hu et al., 2016), but further research is needed to better understand the impacts of ASWs on the environment.

Pesticides

Pesticides are another large-scale source of CECs. Pesticides are omnipresent in land-use practices worldwide such as agriculture, forestry, and horticulture and are also commonly used in both public and private spaces including parks, golf courses, industrial sites, and home lawns and gardens. Pesticides contain a wide array of chemical mixtures and are utilized to prevent, destroy, repel, or mitigate pests. They target specific nuisance organisms by use as herbicides, fungicides, insecticides, bactericides, and more, and are important tools for reducing the loss of harvestable products and landscaping materials, but can run off of land and infiltrate into surface water and groundwater, which is concerning. While many negative effects are known, more research must be done to fully understand the damage that these chemicals can have on plant, animal, and human health. (“National Pesticide Information Center - Home Page,” n.d.).

Surfactants

Surfactants are another common source of CECs. Surfactants are molecules which allow immiscible substances such as oils, dirt, and polymers to be suspended in water. Thus, they are components of many products including detergents, resins, lubricants, and fabric softeners, and are used for a variety of domestic, urban, and industrial purposes (Cowan-Ellsberry et al., 2014; “Surfactants,” n.d.). Without surfactants, products like soaps and fabric softeners would not mix with water, which would make the cleansing and rinsing process much less effective. While some research has shown that frequently used surfactants, such as linear alkylbenzene sulfonates, have no adverse impacts on aquatic or sediment environments at current levels (Cowan-Ellsberry et al., 2014), other research reports that damage to fish gills, altered swimming patterns in blue mussel larvae, and reduced respiration have occurred due to exposure to surfactants (Venhuis & Mehrvar, 2004).

Disinfection By-Products

Disinfection by-products (DBPs) are CECs that form from reactions between naturally-occurring organic matter and disinfectants such as chlorine, chloramines, chlorine dioxide, or ozone (Chowdhury, 2018; Richardson, Plewa, Wagner, Schoeny, & DeMarini, 2007). Individuals are exposed to these chemicals through the ingestion of drinking water, as well as inhalation and contact during activities such as showering, house cleaning, and swimming in chlorinated pools (Chowdhury, 2018). Over 600 DBPs have been identified (Richardson et al., 2007), and the widespread use of disinfectant products, particularly chlorine which is used in great quantities in both the United States and Canada, is concerning due to their potential carcinogenic and endocrine disrupting abilities (Chowdhury, 2018).

Flame Retardants

Flame retardants are classified as chemicals that are mixed or bonded to materials in order to inhibit combustion and/or delay the growth of fire (Hamza et al., 2016). They have been added to a variety of manufactured products such as furnishings, electronics, building and construction materials, and transportation products since the 1970s, allowing them to become persistent in the environment through waste disposal and incineration ("Flame Retardants," 2018). They have the ability to bioaccumulate in humans and animals, and a growing body of evidence suggests that many flame retardants act as endocrine disruptors and carcinogens, as well as impact the immune system and neurological function of humans and animals (Hamza et al., 2016). Research has also shown that children have higher concentrations of flame retardants in their bodies than adults do, most likely due to their hand-to-mouth behavior and their closer proximity to the floor (Butt, Congleton, Hoffman, Fang, & Stapleton, 2014).

Perfluorinated Compounds

Perfluorinated compounds (PFCs) have been widely used in the manufacturing process for commercial and industry products since the 1950s and are added to wetting agents, emulsifiers, paints, waxes, adhesives, polishes, food packaging, and a number of other products to increase these products' thermal and chemical stability (Ledda et al., 2018; Liu, Ma, Yang, Li, & Zhang, 2018; Pal, He, Jekel, Reinhard, & Gin, 2014). They have been found in air, water, soil, wildlife, and the blood and urine of humans (Liu et al., 2018), and tend to exist at higher concentrations in children compared to adults (Ledda et al., 2018). PFCs bioaccumulate and biomagnify in the environment, they are extremely challenging to degrade through common wastewater treatment practices, and research has suggested that PFCs can cause endocrine disorders, developmental neurotoxicity, and attention deficit/hyperactivity disorders (Ledda et al., 2018). Two of the most common PFCs are perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), which may be regulated by the United States Environmental Protection Agency (EPA) in the future due to increasing public health concerns (U.S. Environmental Protection Agency, 2019), and many states are currently taking action to better understand and mitigate the health risks associated with PFC contamination (The Environmental Council of the States (ECOS), n.d.)

Nanomaterials

Nanomaterials (NMs) are another group of contaminants which have come under recent scrutiny, but little is known about NMs relative to other CECs (Lead et al., 2018). They are used in some PCPs, surface coatings, food products, and batteries, and they are also extensively used in biomedical applications (Hamza et al., 2016). Their reactivity and toxicity is largely dependent on their physical and chemical properties (Lead et al., 2018), and studies have indicated that some NMs may accumulate in the lungs, liver, and brain (Hamza et al., 2016). Different types of NMs include organic NMs, fullerenes, carbon nanotubes, and metal-based NMs such as quantum dots (Hamza et al., 2016; Lead et al., 2018). Silver NMs, which are often used in antibiotics and sterilization products to decrease fungal and bacterial growth, have been seen to interfere the balance between oxidant and antioxidant systems in plants, causing eco-physiological stress and potential chronic toxicity (Guo, Cui, Zeng, Wang, & Guo, 2018). Other CECs have garnered greater attention than NMs at the moment, and more research is necessary to better understand these materials and their potential impacts on human health and the environment.

Conclusion

The CECs and potential sources of CECs discussed above are concerning for the health of many living organisms, including humans. This is by no means a comprehensive list of CECs and their sources, but is rather an introduction to some of the better known CECs, as well as some of their known and/or potential impacts. The information currently known about CECs show that they are something to be concerned about and more research is necessary to better understand them and their impacts.

Effects of CECs

While a lot of research has been and is being done to better understand the health concerns associated with living organisms being exposed to and consuming CECs, there is still much to learn about the risks that these chemicals pose. The effects of different CECs on living organisms vary, but abnormal physiological processes, reproductive and immune function impairment, increased incidences of cancer, and the development of antibiotic resistant bacteria are some of the better known health concerns (Chen et al., 2006; Gogoi et al., 2018; Hamza et al., 2016). Endocrine disrupting compounds (EDCs), defined as substances that interfere with the endocrine system and disrupt the normal physiological function of hormones in humans and wildlife, are often present in a number of products, including but not limited to certain PhACs, PCPs, surfactants, DBPs, and flame retardants (Luo et al., 2019). These chemicals either copy or obstruct hormones in the body, primarily estrogen, testosterone, and thyroid hormones, and have many negative impacts on humans and wildlife (Gogoi et al., 2018). Endocrine disruption and reproductive disorders are some of the most common effects of CECs on aquatic organisms (Montes-Grajales et al., 2017) as estrogenic and androgenic EDCs can cause reproductive impairment through decreases in gamete production, mate availability, and fertility (Nilsen et al., 2018). Some CECs, particularly PhACs, are designed to exert biological effects when used, so the existence of non-targeted biological effects from these chemicals are of little to no surprise. While many health consequences from CECs exposure have been identified, there is still much to learn about the impacts that CECs have on living organisms.

Another consequence of CECs being present in water is the promotion of cyanobacterial harmful algal blooms (CyanoHABs) and food web interactions at both the lethal and sub-lethal levels. CyanoHABs alter levels of dissolved oxygen and pH in water, and they also produce toxins and metabolites that have negative impacts on food webs and safe drinking, fishing, and recreational waters (Paerl & Otten, 2016). While eutrophication, caused by increased levels of phosphorus and nitrogen in surface waters has long been considered the main cause for CyanoHABs, more recent research shows that CECs may be a culprit as well (Harris & Smith, 2016). CyanoHABs are less sensitive to pollutants than other taxa and can use nutrients bonded with certain CECs to stimulate their own growth, allowing them to dominate over other species of phytoplankton in waterbodies with higher levels of CECs concentrations (Harris & Smith, 2016). The presence of some PhACs and PCPs, particularly antibiotics, have also been seen to increase the production of the cyanobacterial liver toxin microcystin, meaning that the presence of CECs has been shown to not only increase the number of CyanoHABs blooms, but increase the toxicity of these blooms as well (Liu et al., 2012). These observations raise concerns for increased CyanoHABs blooms in the future as more CECs are released into the environment, and the immediate toxicity effects caused by some CECs, as well as larger picture trophic cascade implications, are concerning.

Wastewater Treatment for CECs

CECs can be released into the environment through many pathways including landfill leachates, surface runoff, atmospheric deposition, leaking sewer lines, and inappropriate waste disposal (Nilsen et al., 2018; Pal et al., 2014), but the predominant source of CECs is sewage effluents originating from residential, industrial, municipal, agricultural, hospital, and laboratory settings (Glassmeyer et al., 2017). Sewage mixtures are sent to wastewater treatment plants (WWTPs) where water is treated and discharged into receiving waters, specifically streams, rivers, lakes, and groundwater (Montes-Grajales et al., 2017). While WWTPs are relied upon to remove contaminants from wastewater, most existing municipal WWTPs fail to remove numerous CECs, particularly complex PhACs and PCPs, as these systems were initially designed to remove biodegradable carbon, phosphorus, nitrogenous substances, and microbes instead (Gogoi et al., 2018). Current regulations do not obligate WWTPs to remove CECs from wastewater, thus ‘treated’ wastewater inevitably contains many CECs (Bai et al., 2018).

A traditional wastewater treatment process contains two or three steps (Gogoi et al., 2018). The first step is primary treatment, where solids such as oils, fats, sediments, and larger plastics are removed. This step is then followed by a secondary treatment process that implements biological treatment techniques to remove organic substances and nutrients. While secondary treatment is often the final step in wastewater treatment, a tertiary treatment is sometimes utilized to remove phosphorus through precipitation and filtration. UV radiation or chlorination can also be used for disinfectant purposes (Gogoi et al., 2018). These traditional treatment processes are not capable of removing the many chemicals that are consistently being developed and utilized, and this inadequacy has led to the investigation of numerous new CEC removal methods in the wastewater treatment process (Glassmeyer et al., 2017; Rizzo et al., 2019). While many of these new treatment techniques look promising for CEC removal, the complexity of mixtures, lack of reliable detection methods, and overall gaps in scientific knowledge make management and treatment extremely challenging. Even certain processes such as biological degradation and photolysis, which are some of the most effective and ecofriendly mechanisms for CEC removal, have the propensity to transform chemicals into derivatives of even greater toxicity (Bilal, Adeel, Rasheed, Zhao, & Iqbal, 2019; Gogoi et al., 2018), so care must be taken to account for and avoid these transformation products when designing and developing new treatment techniques.

Laws, Regulations, and Policies on CECs in the United States

There are many different federal agencies acting under the authority of multiple different laws and policies that attempt to regulate chemical production and utilization throughout the United States. The EPA focuses on governing hazardous chemicals in the United States that are used in industrial and commercial contexts, as well as those that are present in most consumer products, while the Food and Drug Administration regulates food and food additives, drugs, and cosmetics through the Federal Food, Drug, and Cosmetic Act (FFDCA) (Pool & Rusch, 2014). Under the jurisdiction of the EPA alone, the Toxic Substances Control Act (TSCA), Safe Drinking Water Act (SDWA), Clean Water Act (CWA), Comprehensive Environmental

Response, Compensation, and Liability Act (CERCLA), Clean Air Act (CAA), Resource Conservation and Recovery Act (RCRA), and the Federal Insecticide, Fungicide, and Rodenticide Act all attempt to better understand and regulate chemical production and usage. In addition to these Acts there are also programs, such as the Endocrine Disruptor Screening Program and the Toxic Release Inventory Program, that help to better understand and catalog chemicals as well. Regulations and policies on CECs are challenging to develop due to unknown and/or incomplete information regarding their presence, exposure levels, sources and pathways, and health effects (Krimsky, 2017; Pool & Rusch, 2014). The sheer number of CECs being discharged into the environment, along with the complexity of CECs and their transformation products, also makes research and regulation exceptionally difficult, costly, and time consuming. The number of chemicals in commerce increased tremendously during the 20th century, and the rate of increase in chemical usage worldwide is expected to continue or even accelerate as manufactured substances continue to replace natural materials (Pool & Rusch, 2014).

This section will include information about some of the primary laws governing chemical production and use in the United States. While many federal agencies work to better understand and regulate chemicals, this discussion will include a brief overview of action taken by the EPA through the TSCA, SDWA, and the CWA, specifically. The Endocrine Disruptor Screening Program (EDSP) will also be discussed, which is an EPA program. This section will also include some information about current and future plans for CECs regulation as expressed in the EPA's Strategic Plan for Fiscal Years 2018-2022 and will briefly discuss federal regulatory action on specific PFCs as well as the efforts that some states and tribes have made towards regulating CECs.

This discussion is by no means a comprehensive overview of CECs regulation but instead is meant to provide an overview of some of the primary laws governing chemicals in drinking water as well as other important information regarding chemical regulation in the United States. Since CECs are omnipresent and are poorly defined and understood, a comprehensive discussion of all regulatory initiatives for all CECs would require an overview of nearly every attempt made to regulate chemicals in the United States, and such an examination would be beyond the scope of this project and likely distract from the main themes of citizen science and volunteers' awareness of CECs. Thus, this discussion will be focused on some of the primary chemical laws and programs throughout the United States.

The Toxic Substances Control Act

To gain a better understanding of how many chemicals were in commerce and to begin regulating chemical production and usage, the EPA established the Toxic Substances Control Act (TSCA) in 1976. This is the key federal law governing hazardous materials in the United States (Pool & Rusch, 2014). When the TSCA was passed, the EPA produced an inventory of industrial chemicals that were currently in use throughout the United States, which totaled to approximately 62,000 chemicals (Krimsky, 2017). The TSCA technically empowered the EPA to remove chemicals from the market, but in order to do so the EPA had to provide substantial evidence that they were not safe, which was extremely complex and nearly impossible to do, meaning that most chemicals remained in production. The TSCA had separate criteria for new chemicals that were not on the list, requiring that companies notify the EPA of their new chemical, and the EPA then had to decide if the chemical presented an unreasonable risk or potential substantial exposure within 90 days of the notification (Goodman & Thompson, 2018). Due to the short time frame and limited data produced, and the lack of chemical information provided by companies, less than 10% of the chemicals produced between 1979 and 2004 had some form of action taken on them by the EPA, and approximately 85,000 chemicals were on the TSCA inventory list by 2017 (Krimsky, 2017). Recognizing that there was not enough being done to regulate chemicals in the United States, a revised TSCA was passed in 2016 (Krimsky, 2017). The new TSCA requires chemical companies to provide the EPA with toxicity and exposure data for new chemicals so that the agency can better complete hazard evaluations. It also requires a number of other updated mandates to help the EPA make headway in assessing the tens of thousands of chemicals currently in use (Krimsky, 2017).

The Safe Drinking Water Act and the Clean Water Act

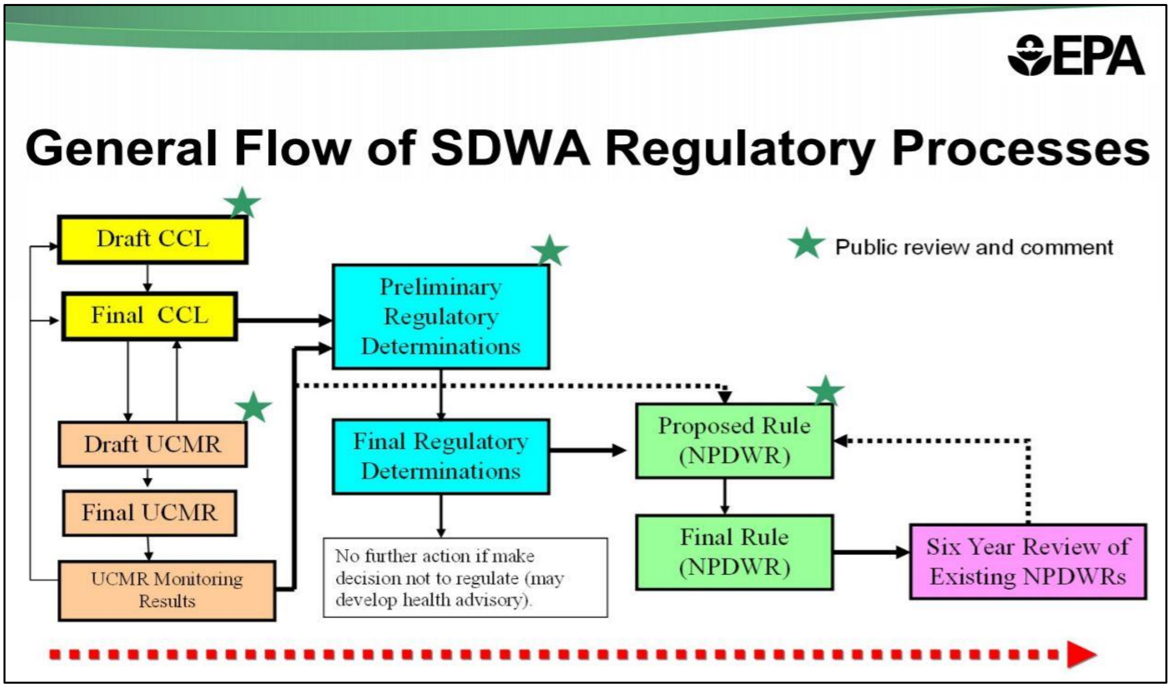
The SDWA and the CWA of the EPA are the two primary laws in the U.S. that aim to reduce contaminants in drinking water specifically, and they have been amended multiple times to keep up with the ever growing number of concerning chemicals being produced and utilized throughout the United States that often make their way into drinking water sources (Duggal, Frede, & Kasky, 2015).

The Safe Drinking Water Act

The SDWA was enacted by Congress in 1974 to protect drinking water sources and regulate the presence of naturally-occurring and man-made contaminants in finished drinking water (Duggal et al., 2015). Under the SDWA, the EPA is responsible for overseeing and setting national standards for contaminants to limit their presence in public water systems (Tiemann, 2017). The EPA does this by first identifying potentially adverse chemicals and studying them further to gain a better understanding of their impacts (Duggal et al., 2015). The EPA then develops a Maximum Contaminant Level Goal (MCLG), which is an unenforceable level at which no known or anticipated adverse health effects occur, which is then followed by implementing a Maximum Contaminant Level (MCL) or a Treatment Technique. MCLs are enforceable standards that are set as close to the MCLG as feasibly possible, and a Treatment Technique is used when an MCL is not economically or technically feasible or when a reliable method to detect a contaminant is not available (Duggal et al., 2015). States then implement drinking water programs that follow federal drinking water guidelines and have primary oversight and enforcement responsibility of public drinking water.

To better handle the large lists of chemicals that were being presented to Congress and the EPA, a process began in 1996 with the most recent amendment to the SDWA wherein the EPA was directed to publish a list of at least five CECs in what is known as the Contaminant Candidate List (CCL), every five years (U.S. Environmental Protection Agency, 2014a, 2018a). There have now been four published CCLs, with a fifth CCL currently in progress. These lists include contaminants which are known or anticipated to occur in public water systems and that have no proposed or promulgated national primary drinking water regulation. Once listed, detailed screening and evaluation of all of the listed chemicals occurs, and no fewer than five and no more than 30 chemicals are then further tested and analyzed. Of those chosen for further analysis, three criteria are utilized as a framework for a preliminary regulatory determination process, which is the beginning of an extended process for deciding whether the EPA should develop a national primary drinking water regulation for a specific contaminant (U.S. Environmental Protection Agency, 2018a). This process can be seen in Figure 2.1. The three criteria are: 1) the contaminant may have an adverse effect on the health of persons; 2) the contaminant is known to occur or there is substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern; and 3) in the sole judgement of the EPA Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems (U.S. Environmental Protection Agency, 2014a).

Figure 2.1 Diagram of the SDWA regulatory process for the contaminant candidate lists.



Note: Reprinted from (U.S. Environmental Protection Agency, 2014a).

To be further considered for official regulation, a chemical must meet all three criteria listed above, meaning that even if a chemical may have an adverse effect on human health and is known or likely to occur in public water systems at a level of public health concern, if the Administrator does not believe that regulation provides a meaningful opportunity for human health risk reduction, the chemical will not be regulated (U.S. Environmental Protection Agency, 2018a). Also, even if a chemical meets all three criteria in the preliminary regulatory determination process, which looks at each chemical based on these three criteria, the EPA can still decide not to regulate a chemical in the final regulatory determination decision following further assessment and monitoring and the required 60 day public comment period. This occurred with strontium, which was on CCL3 and met all three criteria in the preliminary regulatory determination process, but was not on the final regulatory determination list following further research and input (U.S. Environmental Protection Agency, 2014a).

Under this regulatory determination process, the EPA has not developed any national primary drinking water regulations for chemicals on the CCL lists. Table 2.1 includes information regarding all four published CCLs including the year that each list was published, the number of CEC listed in each, the number of CECs analyzed from each list, the year of their formal regulatory decision, and the number of CECs regulated at the end of the regulatory determination process. CCL4 has yet to be prioritized into those which will be further analyzed and CCL5 is still being produced. Lifetime health advisories and other recommendations are often developed following a negative regulatory determination, but enforceable national drinking water regulations are not developed. The SDWA provides the primary regulatory framework for drinking water in the United States and there have been no federal regulations implemented for CECs though this amendment.

Table 2.1 Status of contaminant candidate lists 1 through 4. CCL 4 final determination and formal decision will be made by 2021

CCL	**Year of List Announcement**	**# of CECs Listed**	**# of CECs Analyzed**	**Year of Formal Decision**	**# of CECs Regulated**
1	1998	60	9	2003	0
2	2005	51	11	2008	0
3	2009	116	5	2016	0
4	2016	97	TBA	TBA	0

Note: Data for status of contaminant candidate lists 1 through 4 is from (U.S. Environmental Protection Agency, 2018a) and (U.S. Environmental Protection Agency, 2018c).

The Clean Water Act

The CWA, also run by the EPA, regulates the discharge of pollutants into United States waters and regulates surface water quality (U.S. Environmental Protection Agency, n.d.-d). While the CWA was originally established to control the discharge of conventional point-source pollutants and primarily focuses on these discharges, nonpoint-source pollution and more specifically toxic pollutant discharges have more recently become a larger focus of the Act (Copeland, 2016). Point source pollution is defined as pollution that comes from a single source that can be identified, whereas nonpoint-source pollution cannot be easily attributed to a single source and often occurs over large areas (Environment Protection Authority Victoria, 2018). The CWA requires polluters to obtain permits to discharge any point-source pollution into surface waters, and these permits are state-administered, meaning that the federal government sets standards and states are responsible for the enforcement of and compliance with these standards (Duggal et al., 2015). Effluent limitations are dependent on the designated use of each specific waterbody, and the CWA focuses on minimizing pollution to the extent that it is economically feasible (Duggal et al., 2015).

The Endocrine Disruptor Screening Program

The EDSP, established in 1998, is another avenue through which the EPA is studying CECs. The EDSP is a two tier program that was developed in response to the FFDCA statutory mandate which required the EPA to test and determine the human impacts of substances that may have an endocrine effect and take action if needed to ensure the protection of public health (U.S. Environmental Protection Agency, 2014b). Tier 1 of the program involves screening to see if a chemical has the potential to interact with estrogen, androgen, and/or thyroid hormone systems, while Tier 2 identifies if there is a reaction with the endocrine system and establishes a quantitative dose-response relationship for any adverse interaction effects. The EPA decides which chemicals move from Tier 1 to Tier 2 testing, and those compounds/substances which are still concerning following Tier 2 testing will be addressed through risk assessments. Targeted objectives for fiscal year 2014 through fiscal year 2019 included Tier 1 screening and data interpretation, as well as Tier 2 ecological species tests on birds, fish, frogs, and invertebrates. Tier 1 data has been collected, and 18 of the original 52 chemicals on the list appear to show interaction with the thyroid pathway, meaning that these 18 chemicals will move to Tier 2 testing (U.S. Environmental Protection Agency, n.d.-b). Three final EDSP Tier 2 Test Guidelines have been released, and Tier 2 screening results will be released following the completion of the ecological species tests. The EDSP is slow moving, but it represents a promising step in testing for CECs that could impact the endocrine system.

Strategic Plan for Fiscal Years 2018-2022

The process for regulating chemicals is very rigorous and costly, but it appears as though more progress will be made in the near future to increase regulation on a number of CECs. The EPA released a Strategic Plan for Fiscal Years 2018-2022 with goals aligned with its mission of protecting human health and the environment (U.S. Environmental Protection Agency, 2018b). This plan dictates the EPA will support safe drinking water by focusing research on evaluating the distribution, composition, remediation, and health effects of chemical and biological contaminants. The EPA also states in this plan that it will develop innovative, efficient, and cost effective solutions by 2020 to address known and emerging contaminants which endanger human health, and that one of the Agency's highest priorities is to "[respond] quickly to emerging concerns and [improve] the nation's aging and insufficient drinking water infrastructure to address specific needs" (U.S. Environmental Protection Agency, 2018b). This prioritization presents a promising outlook for future regulations on CECs, and the sincerity of this shift is demonstrated by the recently announced regulatory action regarding per- & polyfluoroalkyl substances.

Current Action on Per- & Polyfluoroalkyl Substances

Per- & polyfluoroalkyl substances (PFAS), a sub-group of PFCs, are a massive group of over 4,000 synthetic chemicals that most people and animals throughout the United States have been exposed to due to their presence in many consumer and industrial products, such as non-stick cookware, stain-resistant household items, waterproof clothing, and grease-repellant food packaging, and their ability to contaminate drinking water sources (Roy, Gold, Jacobson, & Ruckriegle, 2018; U.S. Environmental Protection Agency, 2019). In response to the public's clear desire for immediate action on these chemicals following evidence for potential adverse health effects such as cancer and developmental, liver, immune, and thyroid effects, the EPA released an Action Plan in February of 2019 for two PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS), to evaluate the need for a new maximum contaminant level (MCL), develop groundwater cleanup recommendations, develop toxicity values, and begin designating these two PFAS as hazardous substances through one or more of the EPA's available statutory mechanisms, such as CERCLA, TSCA, CWA, RCRA, and/or the CAA (U.S. Environmental Protection Agency, 2019). This plan entails a great amount of preliminary research into the pathways of exposure, effective methods for removal and remediation, and effects on humans at different concentration levels. Some short-term actions are included in the plan as well, such as developing new analytical methods and tools for understanding and managing PFAS, requiring EPA notification prior to new uses of these chemicals that could cause concern, and using enforcement actions to help manage PFAS risks (U.S. Environmental

Protection Agency, 2019). The EPA plans to propose a national drinking water regulation for PFOA and PFOS in the near future and will be looking to regulate more PFAS in the future as research continues (U.S. Environmental Protection Agency, 2019).

Non-Federal Action

Due to the lack of federal regulations for many concerning chemicals, as well as the ability to impose stricter limits than the federal government, many states and private entities have taken individual action on CECs. States often rely heavily on federal programs to provide information regarding CECs occurrence and toxicity because the EPA often partners with other federal agencies, industry groups, states, tribes, and local communities in data gathering (U.S. Environmental Protection Agency, 2019), but states also have the ability to generate their own toxicity data and adopt their own maximum contaminant levels. In 2016, a compendium was published by Integral Consulting Inc. that evaluated state regulatory initiatives on CECs for all 50 states in the United States and the District of Columbia (*Compendium of State Regulatory Activities on Emerging Contaminants*, 2016). This study found that states such as Montana, Oklahoma, Indiana, and South Carolina relied exclusively on federal actions, guidance, and regulations, whereas states such as Washington, California, Minnesota, New York, and Maine had developed their own specific risk management programs for CECs (*Compendium of State Regulatory Activities on Emerging Contaminants*, 2016). More recently, New Jersey, Vermont, and New Hampshire have adopted or proposed regulations for PFOS and PFOA in drinking water that are just as, if not more aggressive, than the EPAs health advisory levels (BakerHostetler, 2019). A lack of trust in the current political administration to implement adequate and effective federal drinking water regulations has and will continue to contribute to increasing state regulatory actions on CECs, as will the concerns and impacts that CECs impose on the public (Dennis, 2016).

CITIZEN SCIENCE

Introduction

Citizen science, broadly defined as voluntary public participation in scientific research, is a quickly evolving form of science exploration that has grown tremendously in the past few decades (Brouwer, van der Wielen, Schriks, Claassen, & Frijns, 2018; Eitzel et al., 2017). Citizen science incorporates the general public in various aspects of scientific projects such as data collection and analyses, information dissemination, and even theory and hypothesis generation, giving everyday people the opportunity to contribute to scientific endeavors. Similar to museums and science centers, people's participation in citizen science is viewed as an informal route to public education that can achieve both scientific and educational objectives (Bela et al., 2016; Eitzel et al., 2017). Citizen science projects are often led by and done in collaboration with professional scientists and/or public institutions with the goal of addressing specific research questions and generating additional data to help build scientific knowledge (Minkman, Van Der Sanden, & Rutten, 2017). Many environmental and human health fields utilize citizen science to gather immense amounts of data on specific subjects that otherwise likely could not be gathered due to spatial, temporal, and/or financial constraints (Pocock, Tweddle, Savage, Robinson, & Roy, 2017), and these fields are expected to see the largest growth of associated citizen science projects in the coming years (Brouwer et al., 2018).

Terminology Clarification

The term 'citizen science' was adopted in the 1990s and is utilized as a popular umbrella term for phrases such as community-based research/monitoring, participatory action research/monitoring, citizen sensing/monitoring, and crowdsourcing, among others (Eitzel et al., 2017; Goodman et al., 2017; Pocock et al., 2017). All of these different phrases are commonly used in citizen science literature and public engagement is their common denominator. Each name provides more specification as to the type of citizen science being utilized and the purpose of such research, and they can be used together or individually to describe the type and degree of participation in various projects.

Crowdsourcing is a form of citizen science that involves contributions from large groups of people through online collaborations, effectively leveraging the collective intelligence of online communities (Eitzel et al., 2017; Minet et al., 2017). It is the most commonly utilized form of citizen science (Gray et al., 2017) and generally emphasizes micro-tasking and light engagement, as those contributing to crowdsourcing projects generally do not have full understandings of the concepts or implications of such projects (Eitzel et al., 2017). This lack of complete understanding is absolutely acceptable, as full understanding is not required for participants to be valuable contributors (Eitzel et al., 2017). Many different fields utilize crowdsourcing, including astronomy, meteorology, human health, and cartography, but it is most often utilized in gathering environmental and wildlife observations (Minet et al., 2017). Galaxy Zoo, eBird, and Zooniverse are examples of three successful crowdsourcing organizations that are consistently contributed to by online collaborators around the world.

More complex and involved forms of citizen science include participatory action research/monitoring, community-based research/monitoring, and community engaged research/monitoring. While all of these forms of citizen science are similar and are often used interchangeably, they have been distinguished in the literature by a few specific attributes. Participatory action research/monitoring is a form of citizen science that is specifically directed towards social change through a process of research, education, and action (Eitzel et al., 2017), and the focus on social change is what distinguishes this form of citizen science from various others. Community-based research/monitoring engages citizens, government agencies, academia, industry professionals, community groups, and/or local institutions in research associated with specific community concerns (Newman et al., 2017), and community-based projects have the ability to orient towards participatory action-type projects when the collected data is utilized for social change initiatives. Another similar form of citizen science is community engaged research, which is a form of citizen science that aims to address issues that affect the health of marginalized individuals within communities affiliated by geographic proximity, special interests, or similar undesirable circumstances (Goodman et al., 2017). There are many forms of citizen science that are rather similar, but different projects can have different focusses and outcomes dependent on the type of research being conducted, the motivational factors behind such projects for the researchers as well as their collaborators and funders, and the overall structure of the project itself.

Outcomes of Citizen Science

Citizen science projects can benefit participants, scientists, and society as a whole due to their contributions to many different domains of science. Other than the inclusion of volunteer participants, citizen science initiatives are often indistinguishable from conventional scientific approaches involving paid academic, government, non-profit, or commercial organizations, and citizen science projects likewise yield important information for basic or applied sciences (McKinley et al., 2017). Volunteers most often contribute to citizen science projects by collecting data for professional scientists, and the efforts of these volunteers often lead to improved field detections, improved data and image analyses, and refined research questions

(McKinley et al., 2017). While data collection itself and the related results are extremely valuable, there are many other beneficial outcomes associated with citizen science.

Education and Awareness

Citizen science often provides opportunities for participants to learn about and become engaged with scientific research. Through their engagement with different projects, individuals are able to develop new skills and increase their overall scientific literacy, as well as their knowledge and awareness of environmental and/or health issues (Bela et al., 2016; Minkman et al., 2017; Storey et al., 2016). Participants are also then able to share their knowledge and enthusiasm with friends, family, and/or colleagues, which serves as an exposure route for non-involved individuals to science education (McKinley et al., 2017). Citizen science thus provides a pathway for a more informed society by increasing public knowledge and education on scientific subjects.

Stewardship and Democracy

Citizen science projects not only provide pathways for increasing public awareness and understanding of science, but public engagement in citizen science projects is also described as an act of stewardship, form of democracy, and source of empowerment (Eitzel et al., 2017; Pocock et al., 2017; Vann-Sander et al., 2016). Those who become involved with citizen science projects exhibit stewardship through donating their time and energy to a specific cause while expecting no tangible reward in return. Participants in citizen science projects also tend to develop a more established sense of place and have greater affinity for, understanding of, and connection to their home (McKinley et al., 2017; Newman et al., 2017), and those involved in environmentally focused citizen science projects specifically tend to feel strengthened bonds to the Earth and exhibit pro-environmental behaviors in their daily lives (Lewandowski et al., 2017;

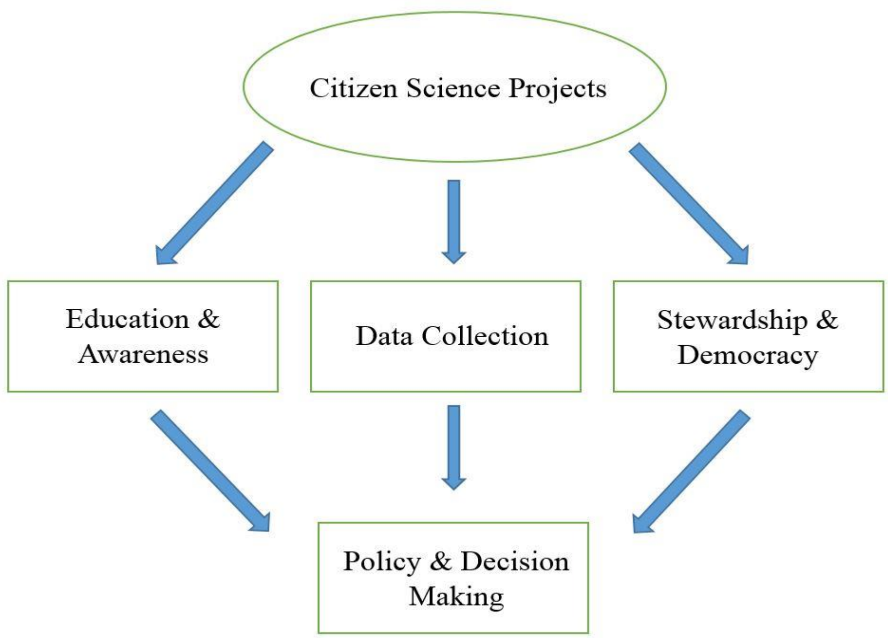
Merenlender, Crall, Drill, Prysby, & Ballard, 2016). Involvement in projects, whether in data collection/generation or in action oriented outcomes, is described by Eitzel et al. (2017) as a form of democracy because many science and policy/decision making processes do not directly involve the general public as often as they should. By providing an avenue for project participants to become immersed in processes that are otherwise reserved for authorities and officials, participation in citizen science can generate a sense of empowerment within individuals. Through their involvement in these projects, individuals and communities are enabled to advocate for their local environment, promoting democratic governance and civic engagement (Eitzel et al., 2017).

Policy and Decision Making

The increased data acquisition, knowledge development, and public engagement offered by citizen science can also benefit policy and decision making on local, regional, and/or global scales (McKinley et al., 2017; Storey et al., 2016). Figure 2.2 visually represents how education and awareness, data collection, and stewardship and democracy all inform/benefit policy and decision making. By everyday citizens and professional scientists working together to address complex issues, citizen science can help to improve management practices, address regulatory gaps, and even raise awareness of previously unrecognized issues (Minkman et al., 2017), thus it is important to foster the growth of public involvement in policy and decision making.

While both the data that is collected and the physical participation of citizen scientists can have numerous positive impacts on policy and decision making processes, it has been noted that there often appears to be a tradeoff in citizen science projects between scientific, policy, or educational goals (Pettibone et al., 2018), meaning that while one or two of these goals may be well-met within a specific project, the other(s) may not be. Policy and decision-making goals often garner less attention than education and scientific goals, and a truly successful citizen science project should greatly emphasize and balance all three objectives (Pettibone et al., 2018). Regulators have disregarded findings from citizen science projects due to the mistrust in data validity, questions regarding the alignment of data collected to acceptable standards, and the potential for political motivations (Jollymore, Haines, Satterfield, & Johnson, 2017), thus more attention should be paid towards these factors to decrease the level of mistrust and increase the use of citizen science data in regulatory and decision making processes.

Figure 2.2 The primary outcomes of citizen science. Education and awareness, data collection, and stewardship and democracy are all beneficial outcomes of citizen science which can help to inform and empower individuals in policy and decision making.



Challenges and Limitations to Citizen Science

While there are many benefits of citizen science, there are also some challenges and limitations which must be recognized and accounted for when developing or partaking in any citizen science project. As with any scientific research, specific challenges vary for each project and are dependent on the type of project and the associated level of involvement. However, there are three commonly discussed challenges associated with citizen science initiatives: data quality, resource requirements, and volunteer-researcher interactions.

Data Quality

One challenge to citizen science projects is data quality, as large amounts of data can be collected but this data can be flawed. Numerous studies have looked into the accuracy and usability of volunteer collected data, and while some research has shown that the accuracy and quality of data is concerning, other studies have shown that citizen science data can be just as accurate as professionally collected data (Alender, 2016; Kosmala, Wiggins, Swanson, & Simmons, 2016; Storey et al., 2016). Some of the main concerns have to do with spatial and temporal data collection factors that can bias or skew data and affect analyses, while other concerns have to do with the ability/skill of participants to collect accurate data (Dickinson, Zuckerberg, & Bonter, 2010; Kosmala et al., 2016; Thornhill, Loiselle, Lind, & Ophof, 2016). Concerns regarding the abilities/skills of participants are often related to factors such as task difficulty, experience, training, and education, as more difficult tasks, less experience, less training, and less educational background on applicable topics can introduce biases and decrease the quality of the data (Kosmala et al., 2016).

Project coordinators have developed a number of strategies to combat the real or perceived issues associated with the quality of citizen scientist generated data. One effective way of mediating these concerns is by adapting project designs to suit citizen scientists' needs, often by making procedures simple, straightforward, and standardized (Dickinson et al., 2010; Kosmala et al., 2016). Some researchers have argued that complex methods and long arduous tasks are not suitable for citizen science projects (Dickinson et al., 2010), and bias can be greatly reduced through the use of simple and standardized equipment and procedures for data collection, particularly by standardizing for timing and location of routine sampling (Mcgoff et al., 2017). Because more complex protocols necessitate advanced training to produce quality data, providing or increasing training is also an effective way to reduce biases. Along these lines, requiring qualifications for volunteers is another beneficial means to ensure that participants have the appropriate skills/abilities prior to collecting data, which can help to increase the likelihood of high quality data being collected (Kosmala et al., 2016). Finally, as a way to review the data collected by participants, data should be validated through statistical analysis and spatiotemporal modeling tools (Kosmala et al., 2016). Filtering out specific data can also be beneficial in certain situations, as research has shown that for many programs, new participants account for most of the data variation (Dickinson et al., 2010). In this case, it may be appropriate not to include data provided by new participants while they are familiarizing themselves with the project and only include their data once they are comfortable with and proficient in the data collection procedures. Project coordinators should be sure to assess the potential biases and inaccuracies of citizen scientists' collected data and adopt appropriate protocols and validation techniques to produce more accurate and reliable information. By utilizing all or some of these tactics, biases and inaccuracies can be accounted for, removed, and/or inhibited.

Resource Requirements

Another challenge that accompanies citizen science projects is the amount of resources that are necessary to effectively implement and complete each project, including those necessary for recruitment, training, supervising, and retaining volunteers. Temporal and monetary investments are common concerns because they are often required in large amounts through different phases of individual projects, and the total costs of long-term engagement and training for participants can be substantial (Dickinson et al., 2010). These costs can be worth the investment though, as research has shown that when properly trained on sampling and data management techniques, volunteers can produce far more data than individual researchers (Dickinson et al., 2010; McKinley et al., 2017). A study completed by Thornhill et al (2016) showed that an investment of one hour of training for volunteers had a return time of more than nine hours of sampling time, meaning that for every one hour of training provided to citizen scientists by professional researchers, citizen scientists completed approximately 9 hours of voluntary research that the professional scientists did not then have to complete. Monetary investments in data management, training, and materials can be costly, but cost reduction measures such as efficient experimental design and effective volunteer training can help to ensure that these resources are not wasted (Dickinson et al., 2010). It is also important to weigh the costs between hiring individuals to collect data and training volunteers to do so instead, and while the required investments for successful citizen science projects may seem daunting, they can be well worth it.

Volunteer-Researcher Interactions

In addition to the issues with data quality and resource investments described above, citizen science projects also face challenges associated with the interactions between professional researchers and volunteers. One common challenge to these partnerships is ensuring that the individual goals of researchers and participants are balanced (Buytaert et al., 2014; Shirk et al., 2012). Researchers may have different goals than volunteers, as researchers may be more interested in the results of a project compared to volunteers who may be more interested in educational and/or community outcomes or the entire process as a whole. Thus, projects should be designed and implemented with all individuals' goals in mind and effectively balance differing desired outcomes (Buytaert et al., 2014). Open, inclusive, and effective communication of goals between citizen scientists and researchers should take place throughout the project development phase and continue throughout the length of the project to ensure that citizen scientists are involved in project decisions and feel as though their desires and knowledge are recognized and appreciated (Vann-Sander et al., 2016).

Without proper communication, balance, and respect, volunteers can feel undervalued, overburdened, and/or exploited for labor, which is undesirable for all parties involved (Alender, 2016; Brouwer et al., 2018; Buytaert et al., 2014). Even if all goals are properly accounted for within a project's design, volunteers can still feel exploited for labor due to the contributory nature of the field of citizen science, so it is important to find a balance between volunteer labor and rewards for such labor. While some volunteers appreciate simply seeing the data collected and the analysis thereof, others appreciate being further recognized for their contributions by receiving hand-written cards, certificates, and/other rewards (Alender, 2016). To better understand how to effectively balance desires of researchers and volunteers, as well as potential rewards for volunteer efforts, it is imperative that project coordinators understand why volunteers became involved in the first place, and what motivates them to continue their participation.

Motivations of Citizen Scientists

Research exploring what motivates individuals to become involved in citizen science projects as well as what helps to retain volunteers is still developing, but the research that has been completed is very beneficial to the field of citizen science by informing project developers' on how to increase participation and prolong involvement in different projects (Alender, 2016; West & Pateman, 2016). While some individuals may be motivated by scientific curiosity or a desire to help with a specific cause, others may simply find joy in participating because they are able to socialize with others or spend additional time in nature. Participants may also experience a change in motivations over time as what may have drawn their interest to a project initially may not be what keeps them involved, or they may begin to care more about the specific issue at hand as they become more informed and invested in a project (Alender, 2016; Buytaert et al., 2014; West & Pateman, 2016). The number of individuals involved in a project is important, as is the continued involvement of those specific participants due to the costs associated with training new individuals, so it is very important to study the motivations of those involved in citizen science projects in order to increase and prolong engagement.

One well established and commonly referred to framework for assessing volunteer motivations was developed by Clary et al. in 1998 and is named the Volunteer Functions Inventory (Clary et al., 1998). This framework identifies motivations in six different categories: (1) understanding, (2) values, (3) social, (4) protective, (5) enhancement, and (6) career. 'Understanding' refers to a desire to learn new things and share knowledge; 'values' refers to altruistic concern for others, the environment, and/or science; 'social' refers to meeting new people and volunteering because it is seen as a socially desirable thing to do; 'protective' refers to reducing negative feelings about one's self; 'enhancement' refers to improving one's self and enhancing self-esteem, and finally; 'career' refers to the hope that gaining experience in a field through volunteering will benefit one's career (Alender, 2016; Buytaert et al., 2014; Clary et al., 1998; West & Pateman, 2016). More detail about each category is provided in Table 2.2. Research has shown that 'values', 'understanding', and 'enhancement' categories tend to be the most important motivators for individuals, while 'career', 'social', and 'protective' tend to be less important (Clary, E. G. and Snyder, 1999). Each category's level of importance is dependent on several factors, and age is particularly relevant because younger volunteers tend to value the career category more than older individuals due to the experience and potential networking opportunities that volunteerism often provides (Alender, 2016). Clary et al. (1998) have also shown that successful recruitment of volunteers is dependent upon how well the project addresses specific motivational factors, and that volunteers' experience greater levels of satisfaction from a project when their motivations are met throughout it (Clary et al., 1998). While motivations differ for each individual, this framework is commonly utilized as the majority of one's motivational factors can be placed into these six categories.

Table 2.2 Motivational framework for citizen science volunteerism. The six different categories utilized in the Volunteer Functions Inventory as a framework for the motivations of citizen scientists.

Category	Conceptual Definition
Understanding	A desire to learn new information and skills, as well as share knowledge.
Values	Altruistic and humanitarian concerns for others, the environment, and/or science driven by one's values.
Social	Strengthening relationships, meeting new people and/or volunteering because it is seen as a socially desirable thing to do.
Protective	Reducing negative feelings about one's self or reduce guilt over being more fortunate that others.
Enhancement	Improving and/or enhancing one's self psychologically. Focus on growth and development.
Career	The hope that gaining experience in a field through volunteering will benefit one's career.

Note: Developed from (Clary et al., 1998).

Volunteer work typically involves 3 stages: a decision to participate, the initial participatory action, and often some level of sustained participation, and all three stages require different effort from project developers to effectively incentivize individuals (West & Pateman, 2016). Awareness of volunteer opportunities, appropriate opportunities for individuals based on differing wants/needs/competencies, and some sort of motivational factor all need to be present in each of these levels (Hobbs & White, 2012), whether the motivational factor be simply the joy of the experience or the results that come from data collection. Studying and adapting projects to participants' motivations and abilities is extremely important for any volunteer program, and the field of citizen science can greatly benefit from a better understanding of what motivates individuals to become and remain involved in different projects.

Citizen Science Water Quality Monitoring

While citizen science is utilized in many different fields of research, water quality monitoring is one important field that particularly relies upon volunteers. 'Water quality' refers to the physical, chemical, and biological characteristics of water and is evaluated by comparing specific samples to designated standards. Different water quality assessments include those for color, odor, temperature, acidity, bacteria content, biological diversity, nutrient loading, conductivity, turbidity, and others (Bardar, n.d.; U.S. Environmental Protection Agency, n.d.-e). Testing can be done for any waterbody, including streams, rivers, lakes, estuaries, wetlands, groundwater, and oceans, and is key for monitoring different aquatic ecosystems around the world. Due to limited resources, paid water quality scientists tend to monitor rivers and streams solely at their mouths, so incorporating citizen science into water quality monitoring programs can allow for data collection to occur more often and at many more locations (Bardar, n.d.).

There are many effective water quality monitoring citizen science programs throughout the world. Examples of two global water quality initiatives are the EarthEcho Water Challenge and the EarthWatch FreshWater Watch program. EarthEcho Water Challenge is a nonprofit organization that runs an annual program from March through December which engages citizens around the world in basic water monitoring processes (“EarthEcho Water Challenge,” n.d.). Individuals are given the opportunity to purchase testing kits through their website, and over 140 countries are involved in water quality data collection for the EarthEcho Water Challenge. EarthWatch FreshWater Watch is another global program and specifically focuses on investigating the health of freshwater ecosystems throughout the world (“Earthwatch FreshWater Watch |,” n.d.). This program asks people to test the freshwater in their local community for agricultural, industrial, and household chemicals by utilizing a pre-designed testing kit, upload their results to an online global database along with a few photos that show the surrounding environment of where they completed their monitoring, and recruit friends and family to sample their own nearby waterbodies. Over 20,000 water quality data sets have been collected through this program, and this data and associated findings are shared with governments, policy makers, businesses, and agencies worldwide to help tackle the challenge of protecting freshwater throughout the world (“EarthEcho Water Challenge,” n.d.).

The United States alone is home to hundreds of water quality citizen science programs that are established in the majority of states throughout the country. Some examples are the Lake Stewards of Maine Volunteer Lake Monitoring Program, the Clean Water Team in California, and the Texas Stream Team. The Lake Stewards of Maine Volunteer Lake Monitoring Program is the oldest and one of the largest statewide citizen lake monitoring programs in the nation, and it trains, certifies, and supports volunteers in testing water quality, assessing watershed dynamics, and screening lakes for aquatic invasive species (“Lake Stewards of Maine Volunteer Lake Monitoring Program,” n.d.). The Clean Water Team is a program of the State Water Resources Control Board in California that incorporates citizen scientists around the state in protecting surface water quality (“SWAMP - Clean Water Team Citizen Monitoring Program,” 2019). The Texas Stream Team is a collaborative project involving Texas State University, the Texas Commission on Environmental Quality, and the EPA, and focuses on gaining a better understanding of and engaging the public in water quality and nonpoint source pollution (Texas Commission on Environmental Quality Nonpoint Source Program, 2019). Hundreds of waterbodies are monitored by all of these programs which help to increase knowledge and awareness of water quality throughout the United States.

One citizen science water quality monitoring program that is especially important to discuss in association with this research is the Citizens Statewide Lake Assessment Program (CSLAP) of New York State. This lake monitoring and education program was established in 1985 and is managed by the New York State Department of Environmental Conservation (NYSDEC) and by the New York State Federation of Lake Associations (NYSFOLA). The goal of CSLAP is to collect lake data, identify problems and changes in the water quality of those lakes, and educate the public about water quality and lake conservation (New York State Department of Environmental Conservation, n.d.-a). Volunteers complete multiple field observation forms that ask about the appearance of their lake, and they are also asked to conduct Secchi Disk tests for water clarity purposes, temperature readings, rake toss sampling for aquatic plant abundance, and multiple other tests which help to understand the water quality of each lake (New York State Department of Environmental Conservation, n.d.-c). Over 100 lakes are monitored each year by CSLAP participants, and over 25 years of data has been collected by these trained volunteers (New York State Department of Environmental Conservation, n.d.-a). This program is extremely important to New York State, as the water quality data that is collected aids in water quality management plans and CSLAP lake reports, and also supports many NYSDEC programs.

CHAPTER 3: METHODS

This study focuses on volunteers who participate in CSLAP water quality monitoring throughout New York State. A paper survey was designed to capture the knowledge that CSLAP participants have regarding CECs and other environmental concerns, as well as the motivations associated with their involvement in CSLAP. The survey was accepted by the Syracuse University Institutional Review Board as IRB# 17-255. This survey was produced with a tailored design, meaning that customized procedures were applied in the development of all aspects of the survey (Dillman, Smyth, & Christian, 2014). The customized procedures were based on the project and researchers goals, the types of people who were to be surveyed, the resources available for doing the survey, and the time frame associated with the project. To improve the survey taking experience as well as increase the response rate, benefits were increased, costs of participation were reduced, and trust was established through a variety of techniques.

Increasing the benefits associated with survey participation is one aspect that helps to improve the survey taking experience and increase the response rate (Dillman et al., 2014). To increase the benefits of those participating in this survey, the introductory section of the survey included a brief couple of sentences explaining the purpose of the entire project as well as the purpose of the survey. Many people feel a significant benefit when helping others, even if they think that they may not gain any personal benefit from helping (Dillman et al., 2014), thus the inclusion of this information in the introduction of the survey may have contributed to the number of responses received as it helped people understand the importance of their responses.

While benefitting survey respondents can be challenging because responding to surveys is usually voluntary and the benefits are generally limited, reducing the costs of participation is greatly beneficial for increasing the number of responses (Dillman et al., 2014). Some tactics used to reduce the costs of participation for this survey included reducing the length of the survey, making it convenient to respond to, reducing the complexity of the survey, and being sure to provide the survey in a means that was comfortable for the intended individuals to respond to. The following paragraphs will include a discussion of each of these factors which helped to reduce the costs of participation.

The survey was designed to take approximately 15 minutes to complete and included 23 questions total, six of which were optional demographic questions. It was important to ensure that this survey would take a short amount of time for participants to complete, as shorter surveys tend to garner greater response rates than longer surveys because length is a large cost to respondents (Dillman et al., 2014). The majority of surveys were distributed and collected on May 5, 2018 at the 35th New York State Federation of Lake Associations (NYSFOLA) Annual Conference in Lake George, New York. Thus it was also important that the time required to take the survey did not interfere with conference activities, which meant that a shorter survey was more applicable to the situation. Surveys were provided to as many NYSFOLA attendees as possible, and approximately 10 surveys were returned via the mail by respondents who either were unable to attend the NYSFOLA conference but were still interested in completing the survey, or by those who didn't finish it at the conference but still wished to submit it.

By administering this survey to the NYSFOLA Annual Conference attendees while they were at the conference, it was much more convenient for respondents to complete the survey and submit it. This survey was passed out to attendees at the conference by project researchers, and respondents were able to easily place their survey in an enclosed box at the registration table once it was complete. This not only allowed respondents to experience ease with submitting their completed surveys, but also allowed researchers to have the majority of the survey responses by the end of the conference day.

This survey was also designed to be straightforward and uncomplicated. The goal of this research was to gain a basic understanding of where citizen scientists knowledge stood in respect to CECs, as well as what motivated them to volunteer in water quality monitoring, and a simple and straightforward survey would allow for those goals to be met. Extensive detail can easily deter individuals from responding to a survey, as well as questions that require a large amount of thought and time (Dillman et al., 2014), thus complex questions were avoided. This survey was visually standardized and was designed to be easy to read, comprehend, and complete.

Finally, to further decrease the costs associated with participation, surveys were dispersed in a mode that would encourage completion by the target population. This dispersal mode that was chosen was a paper survey, rather than an internet or phone survey. Some people are uncomfortable with responding to specific modes of surveys and it is important to keep the intended study population in mind when developing survey methods (Dillman et al., 2014), thus knowing that a large majority of the study population would be older adults, including many over the age of 60 years, it was decided that a paper survey would be the most comfortable way for individuals to complete the survey. While mixed-mode surveys are commonly utilized in survey research, the mixed-mode design has primarily been developed due to concerns over coverage and low response numbers (Dillman et al., 2014), which were not of concern for this research. Due to lack of concerns for those factors, as well as the need to benefit and adapt the survey to the targeted population, a paper survey was the best option for this research.

Increasing the benefits and decreasing the costs of participation are important variables to consider in survey methods, as is establishing trust (Dillman et al., 2014). Multiple factors helped to establish trust between researchers and respondents, including the implementation of the survey at the NYSFOLA conference, applying the names and logos of Syracuse University and SUNY-ESF to the top of the survey, and assuring confidentiality of answers. Administering the survey at the NYSFOLA conference with all project researchers present likely increased trust and benefitted the response rate, as it has been noted that legitimate surveys have sponsors who are willing to identify themselves (Dillman et al., 2014). Including the university's logos on the survey also likely increased levels of trust and benefitted the response rate because people are more likely to comply with a request if it comes from an authoritative and legitimized source, and universities are authoritative sources that have been legitimized by society (Dillman et al., 2014). In respect to confidentiality, a sentence was included in the introductory paragraph of the survey that stated that the results of the questionnaire would be treated anonymously. All of these factors helped to increase trust between researchers and participants, which likely increased the survey response rate.

The survey consisted of both closed and open-ended questions, and question types included multiple choice and Likert-scales with a four-point response format. Some questions included two parts to gain more information, the first part being a closed ended question and the second part being an open-ended follow-up question. These follow-up open-ended questions were either descriptive response open-ended questions or numerical response open-ended questions. Some questions were also partially closed-ended questions due to the inclusion of an open-ended 'other' response following multiple closed-ended response categories, meaning that these questions were a hybrid of closed and open-ended formats (Dillman et al., 2014). All questions were developed using information from previous studies and information provided by key informants at different points throughout the project development process. Question 11 was replicated from the Gallup Poll ("In U.S., Water Pollution Worries Highest Since 2001," n.d.), and questions 12 and 16 were adapted from Vann-Sander et al. (2016) and the Institution of Environmental Sciences (Kragh, 2016), respectively. The remaining questions are original to this study and were designed to gauge the knowledge and motivations of CSLAP volunteers.

In total, 52 surveys were received. Seven of those 52 surveys were removed from data analysis for lack of CSLAP experience from the specific respondent. The preliminary question regarding CSLAP involvement was utilized to removed unwanted responses, meaning that those who answered 'no' or failed to answer the question about if they were involved with CSLAP sampling or monitoring were removed from the analysis because the target population were those who were currently involved with monitoring. After removing these responses, 45 surveys remained for analysis. While most respondents answered all questions on the survey, some individuals skipped certain questions as respondents were not required to complete every question on the survey. Data collected from survey respondents was confidentially entered into Survey Monkey software due to the convenience, efficiency, data storage abilities, and graphic display options of the software. The data was then exported from Survey Monkey to Microsoft Excel where figures were created and analyzed for this thesis.

CHAPTER 4: RESULTS

This section includes an overview of the demographics of this study population, as well as the individual question responses. Figures and tables are provided to display the results of the survey questions. The title of each figure refers to the topic of the question and the full question, as well as a written explanation of the results, can be found in the description provided below each figure. Tables are present where open-ended questions were asked, and the responses to those open-ended questions are therein. To view the survey itself, please refer to Appendix C.

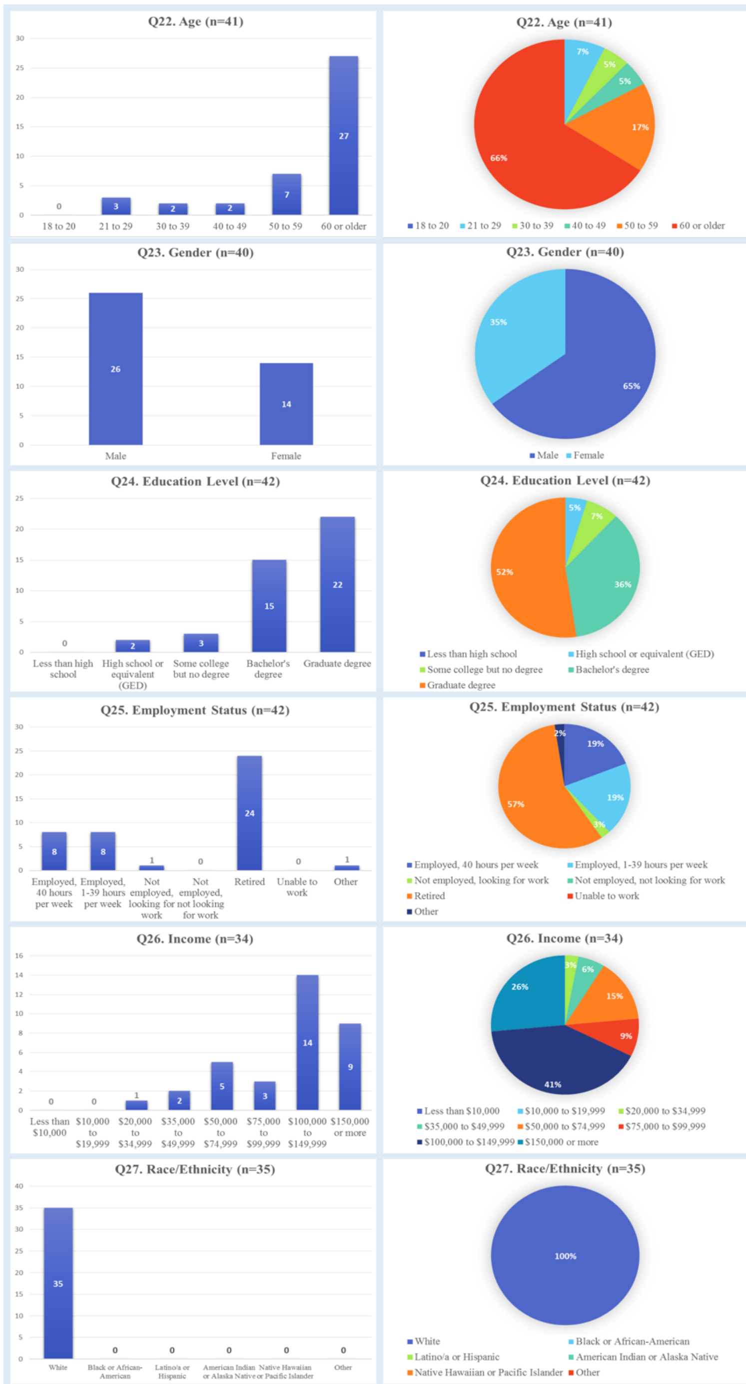
DEMOGRAPHICS

The demographics questions on this survey were marked as optional, so while many did complete all prior survey questions, some chose not to complete all or some of the demographics questions. This is particularly noticeable on the questions regarding income and race, where an average of seven fewer individuals chose to respond compared to the other demographic questions.

Of those who responded, volunteers represented many age groups, from 21 years of age to more than 60 years of age. Most respondents were over age 50 (83%), and the age group with the most responses were those age 60 or older (66%). The responses were approximately 1/3 female (35%) and 2/3 male (65%). Most respondents were well educated, with 36% holding a bachelor's degree and 52% holding a graduate degree as their highest level of degree completed. Most respondents were retired (57%). About 1/5 (19%) were employed and working 40 hours or more per week, while another 19% worked 1-39 hours per week, meaning part-time. Of the respondents who reported total household income, the majority earned over $100,000 per year (67%), with 41% earning between $100,000 and $149,000 and 26% earning $150,000 or more.

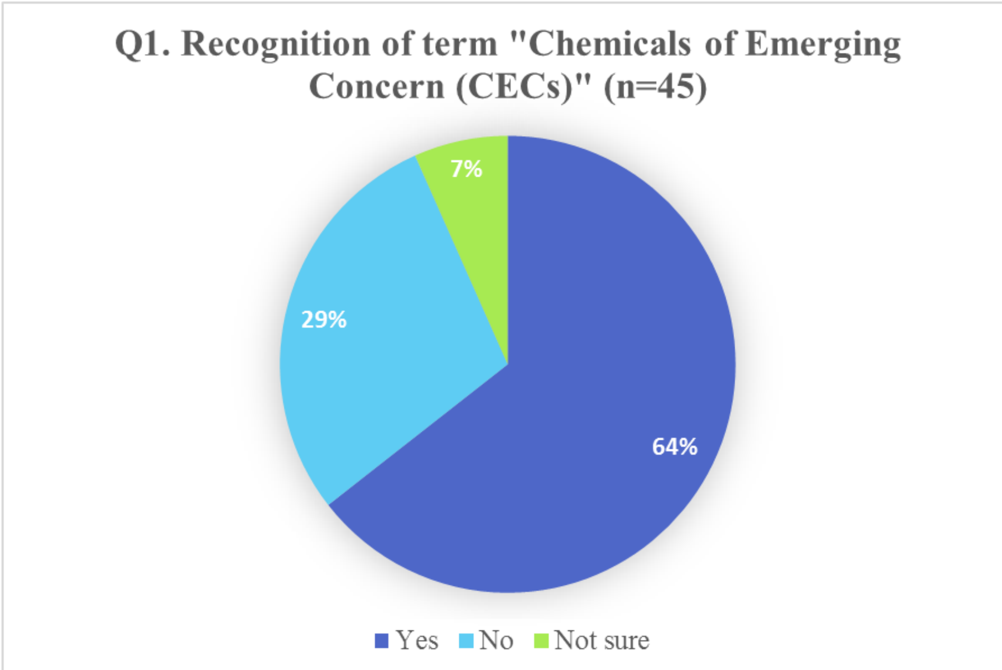
All respondents identified their race as white. Figure 4.1 is provided below which includes all demographic data in both bar and pie chart format. A table with all demographic data is also provided in Appendix B.

Figure 4.1 Demographics of sample. Age, gender, education level, employment status, income, and race/ethnicity of respondents in both bar and pie chart format.



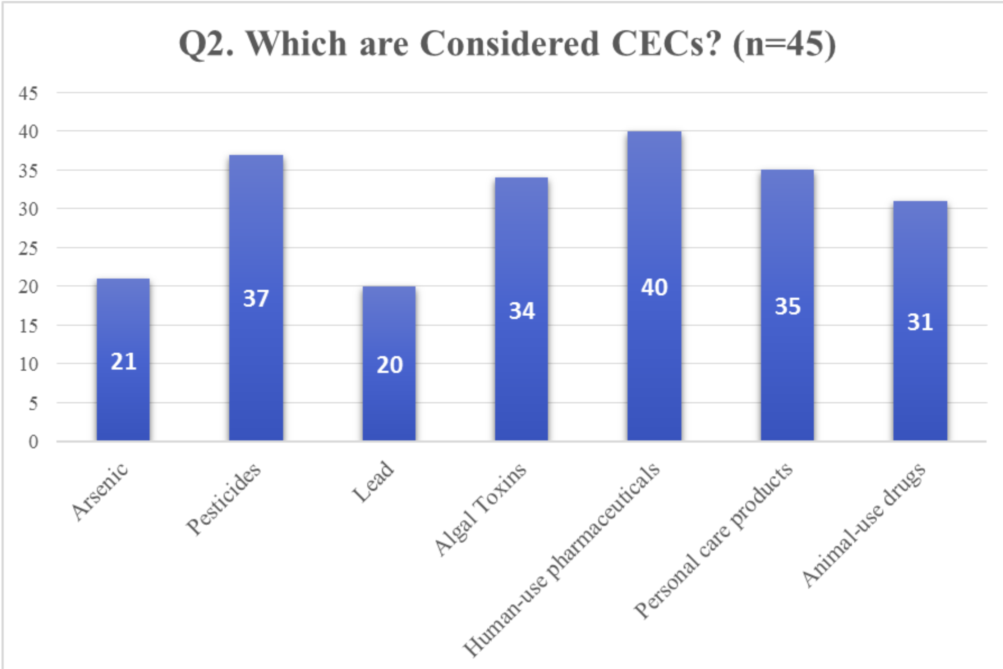
QUESTIONS 1-17

Figure 4.2 Question 1. Recognition of the term “chemicals of emerging concern (CECs)”



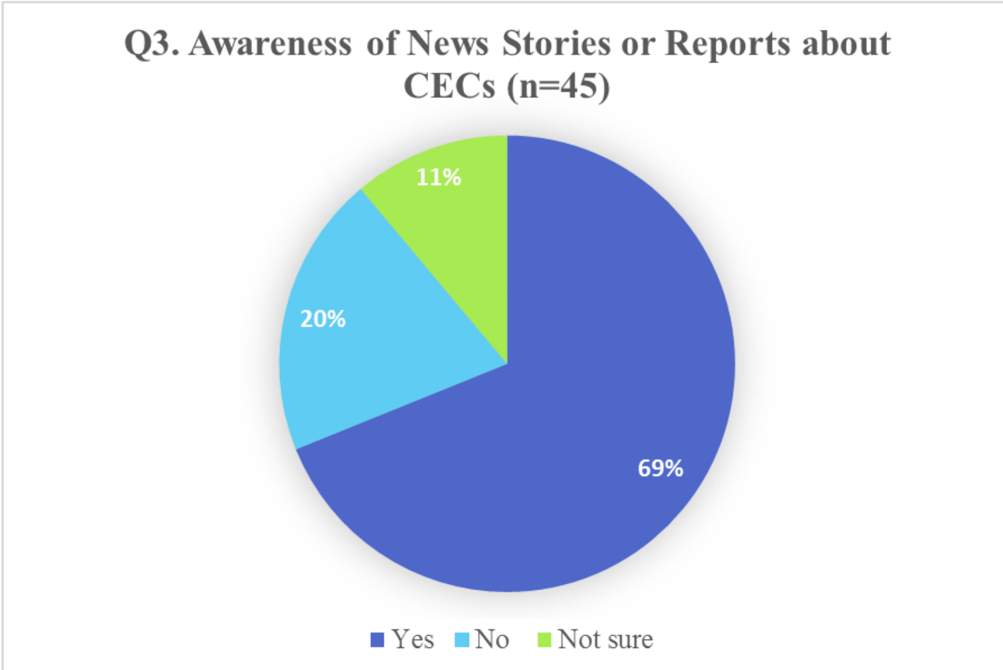
Respondents were asked to answer the question, “Have you ever heard of the term, ‘chemicals of emerging concern’ (CECs)?” and were provided with response options of ‘yes’, ‘no’, and ‘not sure’. All 45 individuals responded to this question: 29 (64%) responded ‘yes’; 13 (29%) responded ‘no’; and three individuals (7%) responded “not sure”.

Figure 4.3 Question 2. Which of the following are considered CECs?



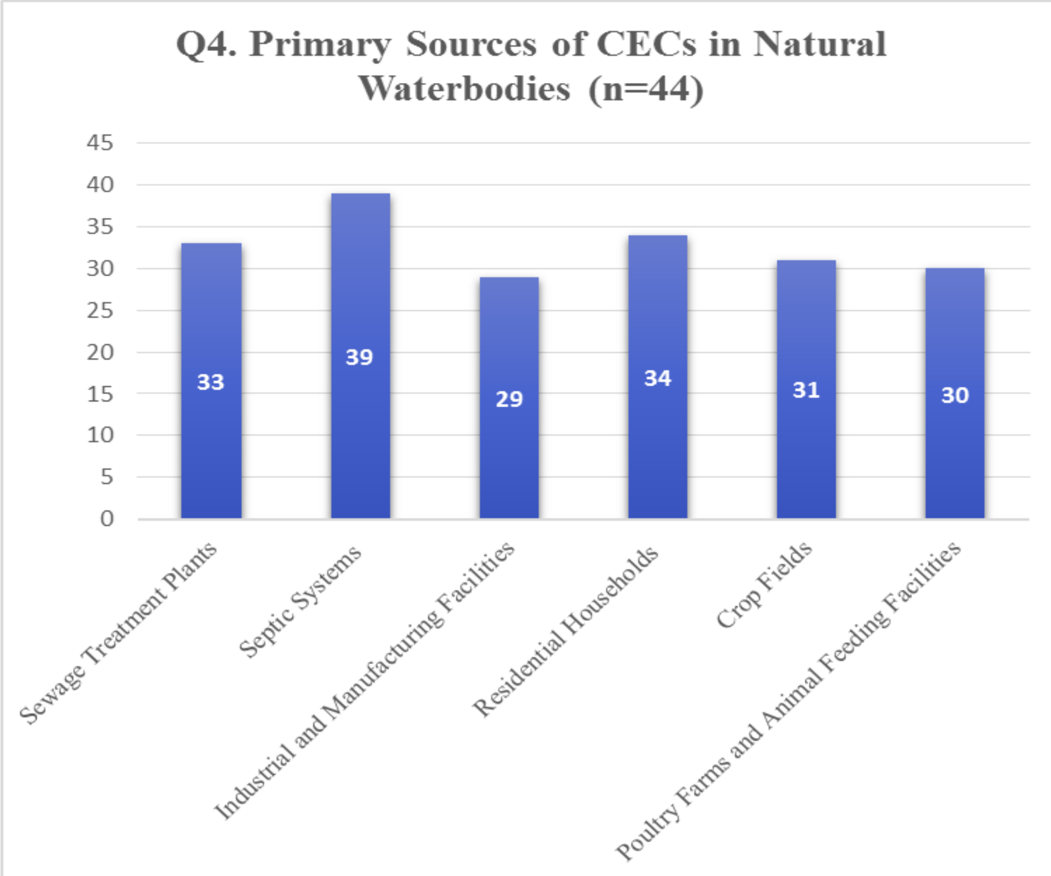
Respondents were asked to answer the question, “Which of the following might be considered as CECs? Select one or more as you see fit” and were provided with response options of ‘arsenic’, ‘pesticides’, ‘lead’, ‘algal toxins’, ‘human-use pharmaceuticals’, ‘personal care products’, and ‘animal use drugs’. All 45 individuals responded to this question by choosing at least one of the options. Twenty-one (47%) of the 45 respondents chose ‘arsenic’; 37 (82%) chose ‘pesticides’; 20 (45%) chose ‘lead’; 34 (76%) chose ‘algal toxins’; 40 (89%) chose ‘human-use pharmaceuticals’; 35 (78%) chose ‘personal care products’; and 31 (69%) of the 45 respondents chose ‘animal-use drugs’. Options that were not chosen by a respondent were considered to not be a CEC by that specific respondent.

Figure 4.4 Question 3. Awareness of news stories or reports about CECs



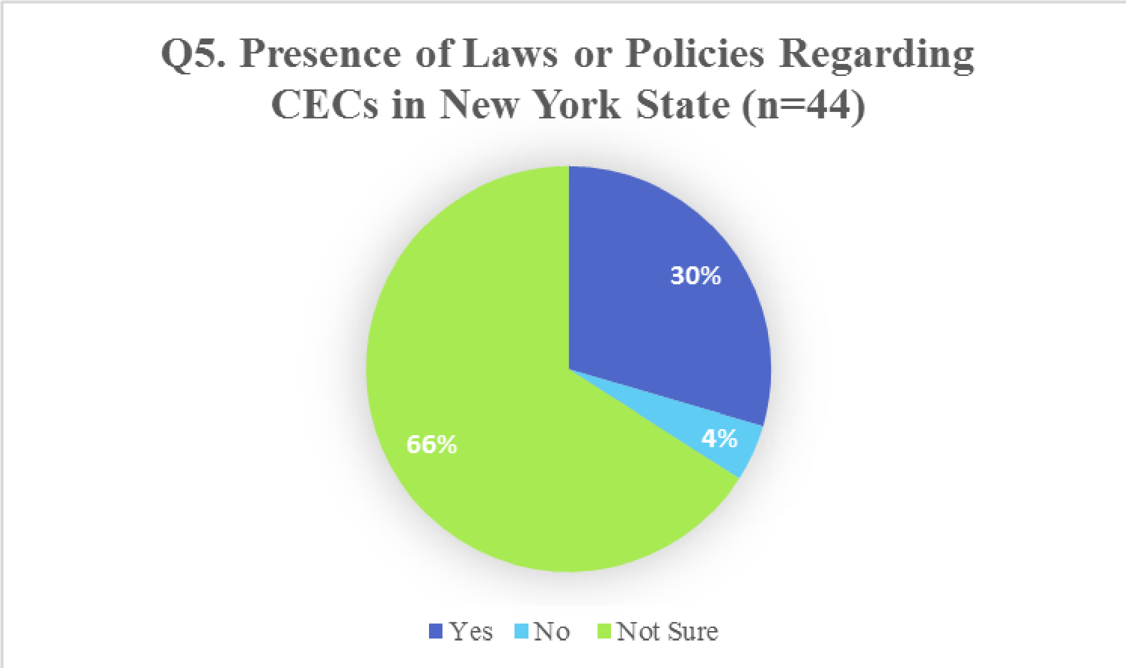
Respondents were asked to answer the question, “Are you aware of any news stories or reports about the presence of CECs in New York State’s waters (lakes, streams, etc.)?” and were provided with response options of ‘yes’, ‘no’, and ‘not sure’. All 45 respondents answered this question. Thirty-one (69%) responded ‘yes’; nine (20%) responded ‘no’; and five (11%) responded ‘not sure’.

Figure 4.5 Question 4. Primary sources of CECs in natural waterbodies



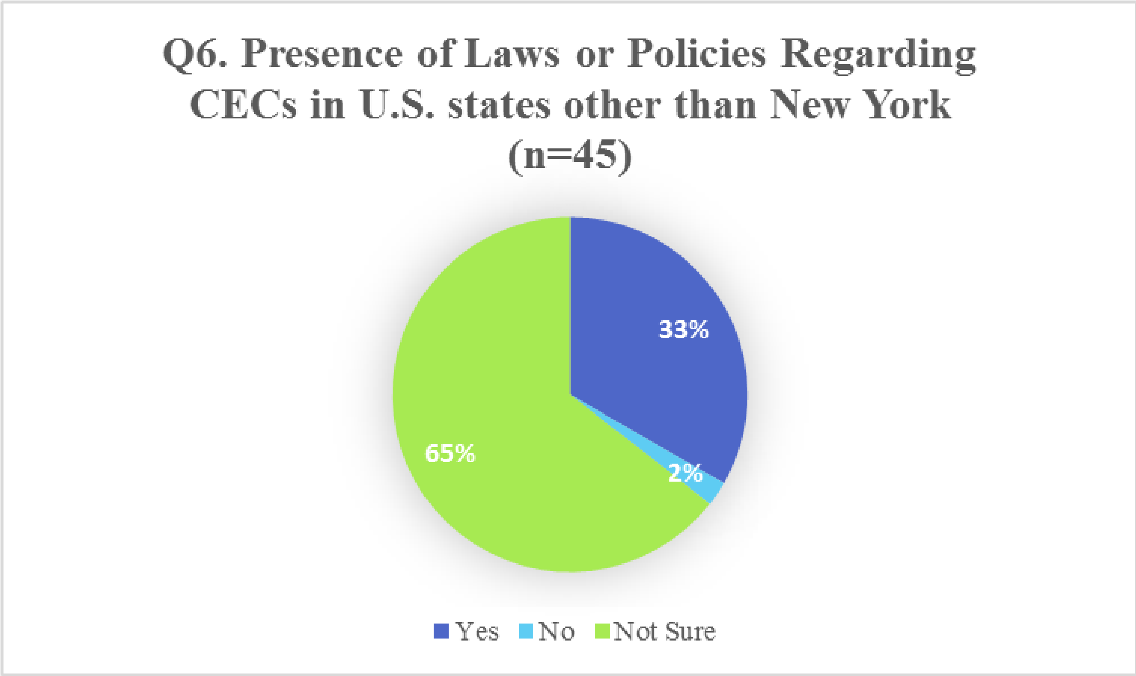
Respondents were asked to answer the question, “What are the primary sources of CECs in natural water bodies? Select one or more as you see fit” and were provided with response options of ‘sewage treatment plants’, ‘septic systems’, ‘industrial and manufacturing facilities’, ‘residential households’, ‘crop fields’, and ‘poultry farms and animal feeding facilities’. Forty-four individuals responded to this question. Thirty-three (75%) of the 44 respondents answered ‘sewage treatment plants’; 39 (87%) chose ‘septic systems’; 29 (66%) chose ‘industrial and manufacturing facilities’; 34 (77%) chose ‘residential households’; 31 (70%) chose ‘crop fields’; and 30 (68%) of the 44 respondents chose ‘poultry farms and animal feeding facilities’. Options that were not chosen by a respondent were considered to not be a primary source of CECs for that specific respondent.

Figure 4.6 Question 5. Presence of laws or policies on CECs in New York State



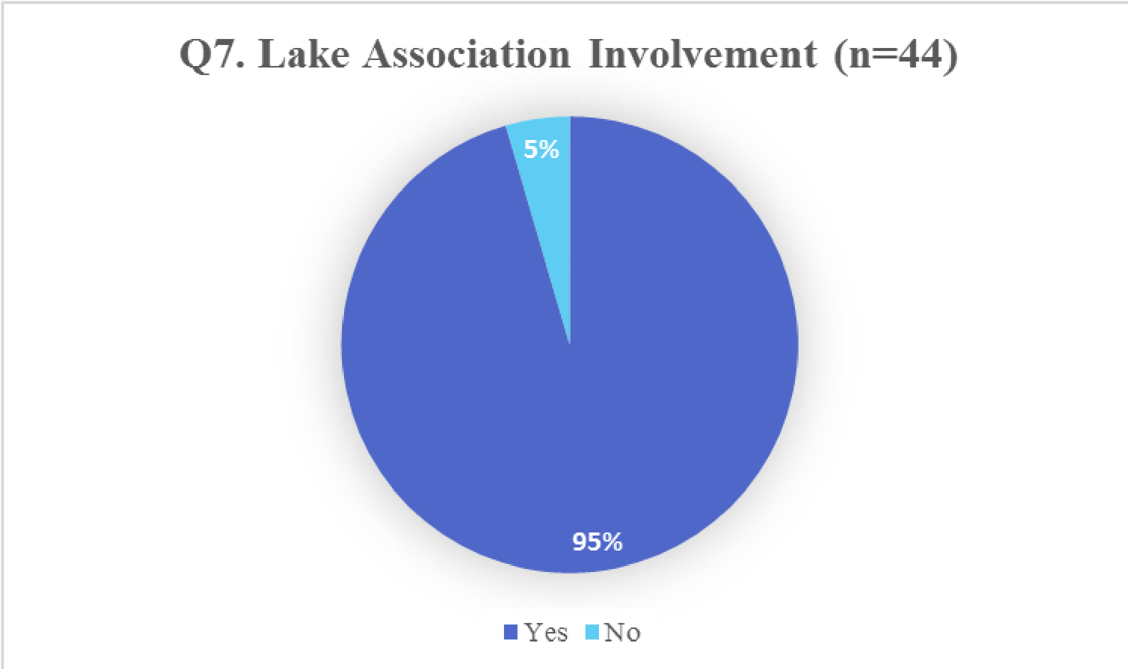
Respondents were asked to answer the question, “Are there laws or policies regarding CECs in water, in New York State?” and were provided with response options of ‘yes’, ‘no’, and ‘not sure’. All 45 respondents answered this question. Thirteen responded ‘yes’ (30%); two responded ‘no’ (4%); and 29 individuals responded “not sure” (66%).

Figure 4.7 Question 6. Presence of laws or policies on CECs in U.S. states other than New York



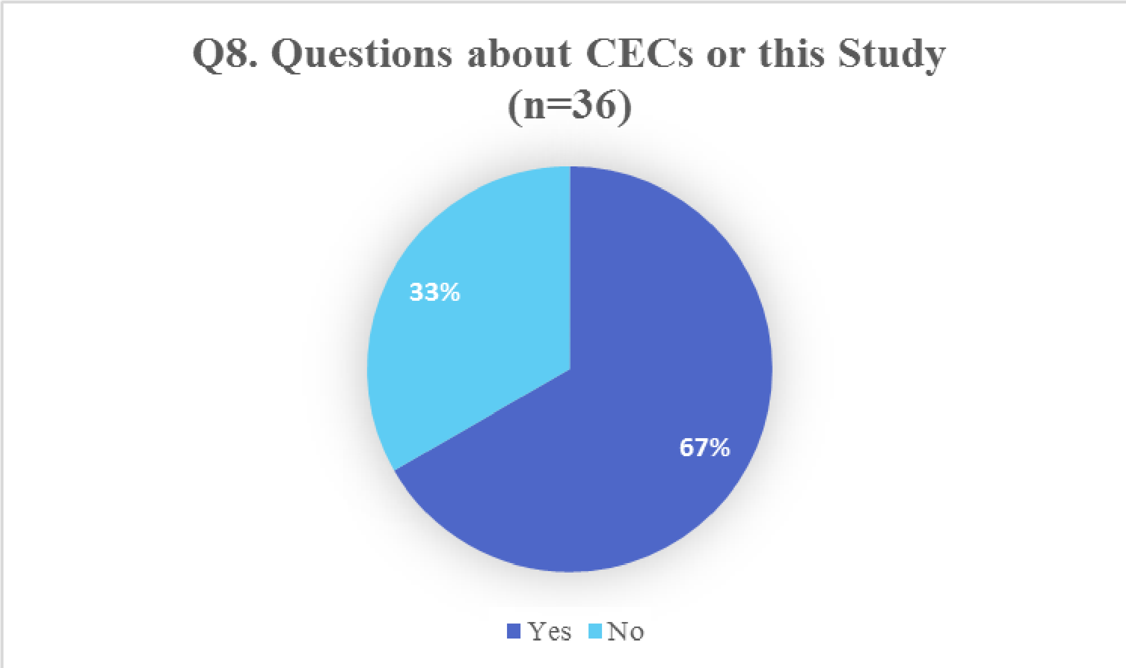
Respondents were asked to answer the question, "Are there laws or policies regarding CECs in water, in U.S. states other than New York?" and were provided with response options of 'yes', 'no', and 'not sure'. All 45 respondents answered this question. Fifteen responded 'yes' (33%); one responded 'no' (2%); and 29 individuals responded "not sure" (65%).

Figure 4.8 Question 7. Involvement with a lake association



Respondents were asked to answer the question, “Are you involved with a lake association?” and were provided with response options of ‘yes’, ‘no’, and ‘not sure’. Forty-four respondents answered this question, 42 of whom said ‘yes’ (95%), and two said ‘no’ (5%). Respondents were also asked “if so, which one?” to which 41 individuals left a response naming the specific lake association they are involved with. Twenty-nine different lake associations are represented here.

Figure 4.9 Question 8. Questions about CECs or this study



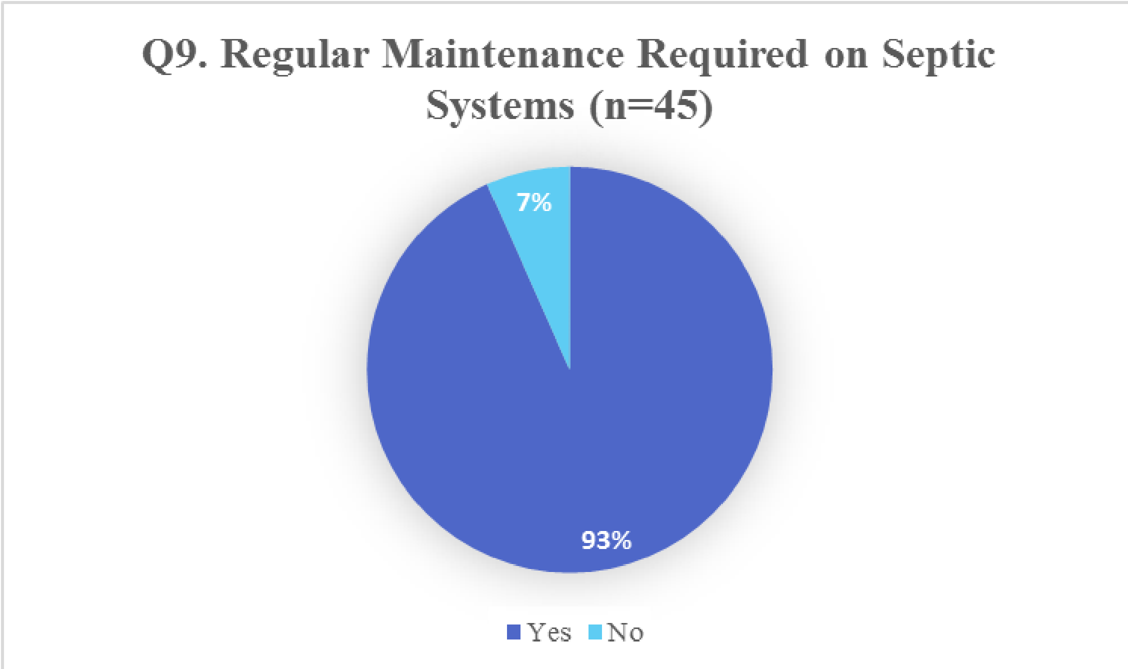
Respondents were asked, "Do you have any questions regarding CECs (e.g., behavior, route of exposure, occurrence, toxicity, treatment technologies, etc.) or about this study?" and were provided with response options of 'yes' and 'no'. They were also asked to list their questions in the space provided below the question. Thirty-six individuals responded to this question, 24 of whom responded with 'yes' (67%) and 12 of whom responded with 'no' (33%). Twenty-five individuals wrote down their various questions/comments, and those responses are provided in the table below.

Table 4.1 Written responses to survey question 8

Q8. Written Responses
Can certain human-produced chemicals be used to trace point or non-point pollution sources? i.e. animal antibiotics trace source to a farm
All of the above... This is the first time I've heard of this study. I am not a full time resident (5 months) at Hadlock. I live in New Jersey for about 7 months. So, I haven't heard anything about chemicals in the water... except PFOA's from chemical plants in Hoosic Falls, N.Y. affecting their drinking water.
All of the questions listed above - very limited knowledge

Best practices for citizen avoidance/remediation
Among the CECs I checked above, some I'd judge as not being "emerging" (e.g. Arsenic, Lead)
Mostly just curious to know which CEC's affect Otisco Lake. How/what is the impact? What are they? Where do they come from?
Is your lab CEC certified? What are the individual CEC's you are analyzing for?
Would be interested in a summary of the current understanding of CECs and how is this study helping and what organization is funding it? Are there any other organizations or agencies working on CECs?
Septic. Farm spreading
If found in our lake will there be follow up + help from ESF
Impacts on water quality, human health
Not sure what can be done
Medicines used by individuals on septic systems. Does filtration remove medicines secreted by individuals before they enter the lake?
When + how will the results of this study be made available?
How will the information be used?
What can be done at the source to reduce the entrance of CECs to waterbodies & the environment
fracking water applied on roads as a salt replacement or dust inhibitor
Poultry Processing Plant 100' from lake. Town put in vortex drain but also they wash the trucks that haul live chickens all that mess washes into lake. Fecal tests about 6000! yuck
Probably many, but mainly... is there any immediate risk to swimming or recreational contact with CECs?
What are your plans to expand and integrate with CSLAP
No need. Douglas C. 1. Willing to do additional sampling for you 2. Sampling should be undertaken even though most treatment facilities cannot treat for. Need to know what problems need solved before it is too late and harm occurs.
How to sample/ How to add to existing sampling programs or new sampling programs
Too many to list. An overview of CEC's would help.
Since I am unaware of any CEC's, I need to learn about ALL of them.
Will plastics be included? Will glyphosate be included?

Figure 4.10 Question 9. Maintenance requirements for septic systems

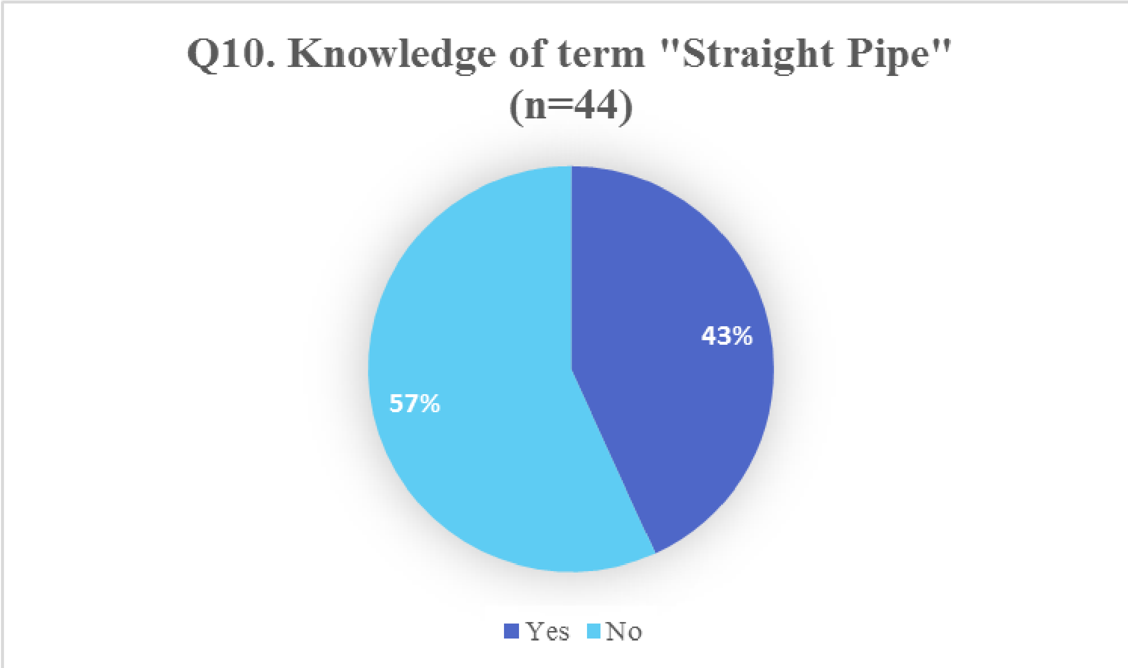


Respondents were asked to answer the question, “Do septic systems require regular maintenance?” and were provided with response options of ‘yes’ and ‘no’. All 45 respondents answered this question. Forty-two respondents said ‘yes’ (93%) and three respondents said ‘no’ (7%). An open ended question was also included which asked “if so, how frequently?” meaning that those who responded yes could also note how frequently septic systems require maintenance. Thirty-eight respondents answered the following open-ended question regarding the frequency of regular maintenance and a wide variety of responses were given. These responses are provided below.

Table 4.2 Written responses to survey question 9

Q9. Written Responses	
2-4 years depending upon # of people in residence	Should be pumped ~ 4 years
1 time a year minimum	2-3 years pump out, baffle check
1-3 years	3-5 year pump out of tank for solids
1-2 years pumping	Septic tanks pumped every 3 to 5 years
Once a month	Annual
Annual	Every 3-5 years - depending on size of household, pattern of occupation
Annually or to address problems	every 3 years
3-5 years depending on use	Pumping every 3-5 years
4 years	Depends... but by our town's law, inspected at least once every 5 years
Depends	Annual
Three years	5 years
2-3 years -> pumped	every 2 years
Every 5 years?	~ every 3 years, though seasonal use systems may be ok at 3-5 years
2 years or as needed	3-5 years
Annually	Don't know
Depends on # of residents, summer home etc.	Depends on tank and family size ~ 3 to 4 years
4-6 years. Pumped out	Depends on size of tank + use
Not sure	Septic companies say 5 years - BUT not enforced to my knowledge
3-5 years	Pumped every year

Figure 4.11 Question 10. Knowledge of the term “straight pipe”

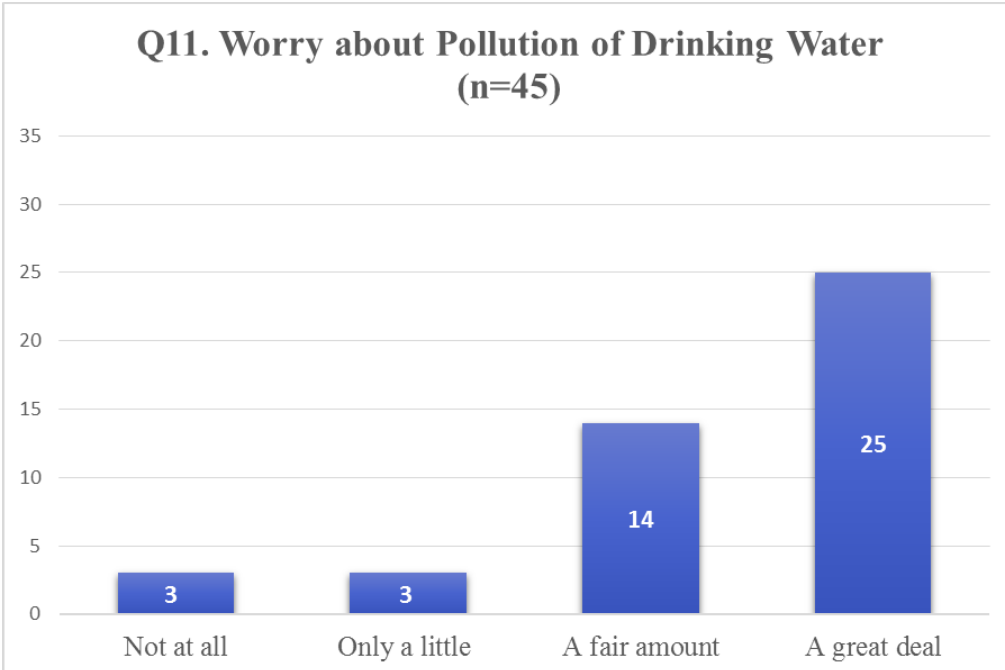


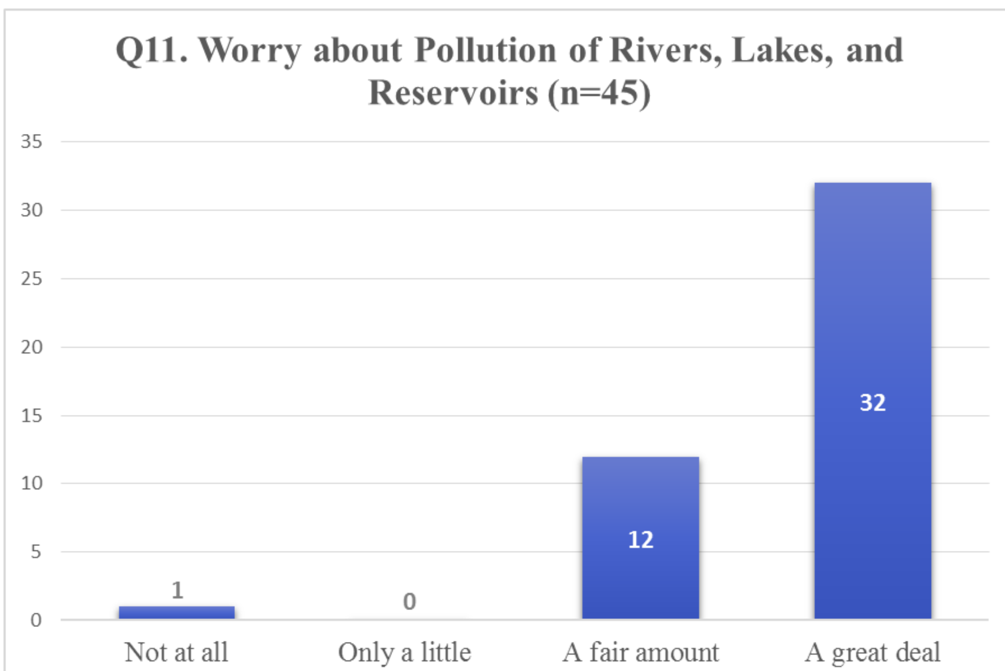
Respondents were asked to answer the question, “Have you heard the term ‘straight pipe’?” and were provided with response options of ‘yes’ and ‘no’. Forty-four respondents answered this question. Nineteen respondents said ‘yes’ (43%), and 25 respondents said ‘no’ (57%). An open ended option was also included which asked “if so, please explain” meaning that those who responded yes could also write what they thought a straight pipe is in the space provided. Eighteen respondents answered the following open-ended question asking for an explanation of what a straight pipe is and a wide variety of responses were given. These responses are provided below.

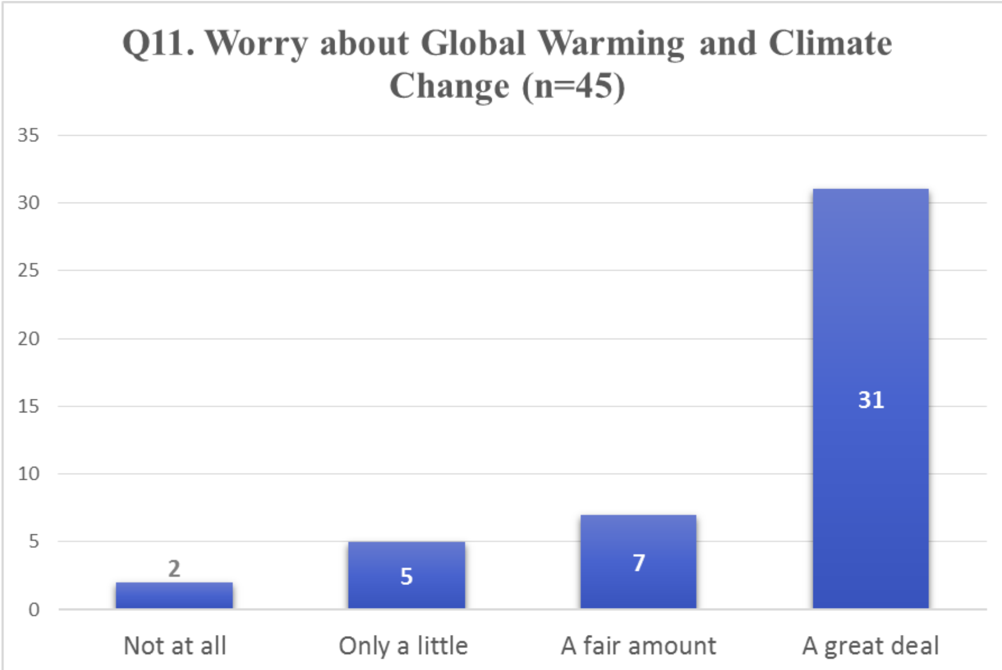
Table 4.3 Written responses to survey question 10

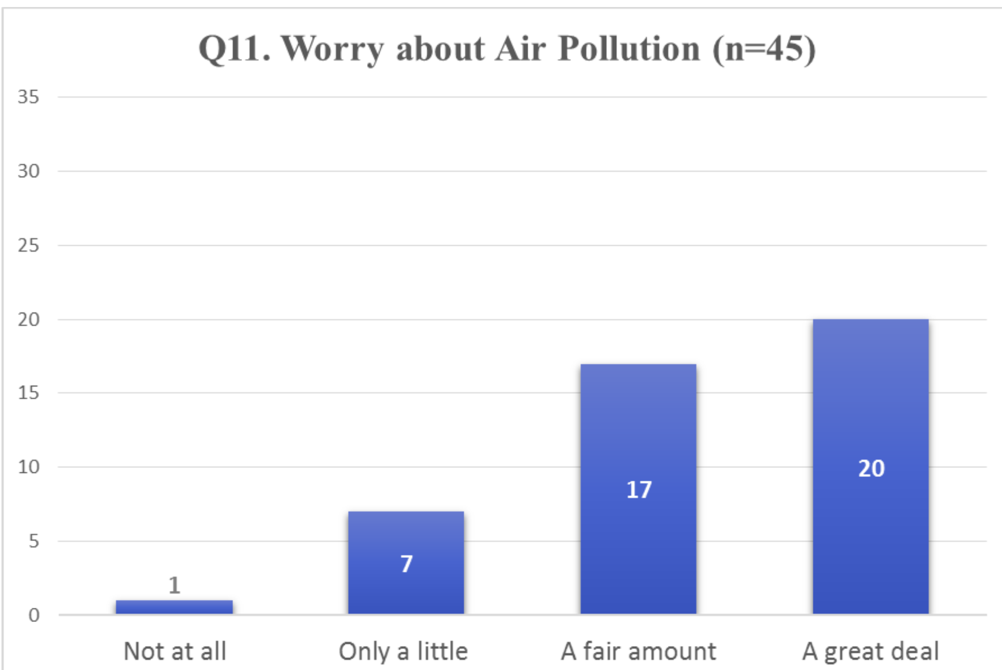
Q10. Written Responses
Sewage to lake
Absence of approved septic system
No treatment sewage disposal into a waterway
Outfall
A pipe that flows (+ empties) straight into a water body
Straight pipe to the lake!
Pipes that dump liquid/solid waste directly into a body of water
House to lake, no septic sys.
Yes, a pipe that goes straight into the lake or toxins that drain straight into the lake
Discharge directly - without the use of any filtration
Means of waste disposal?
Direct discharge into water body
Any pipe that discharges directly into a water body.
Untreated materials can go from source to outflow
Direct flow of sewage/gray water or storm water?
Direct discharge to waterbody. No treatment.
No leach field, direct dumping
Transports raw or partially settled sewage directly to a lake or stream

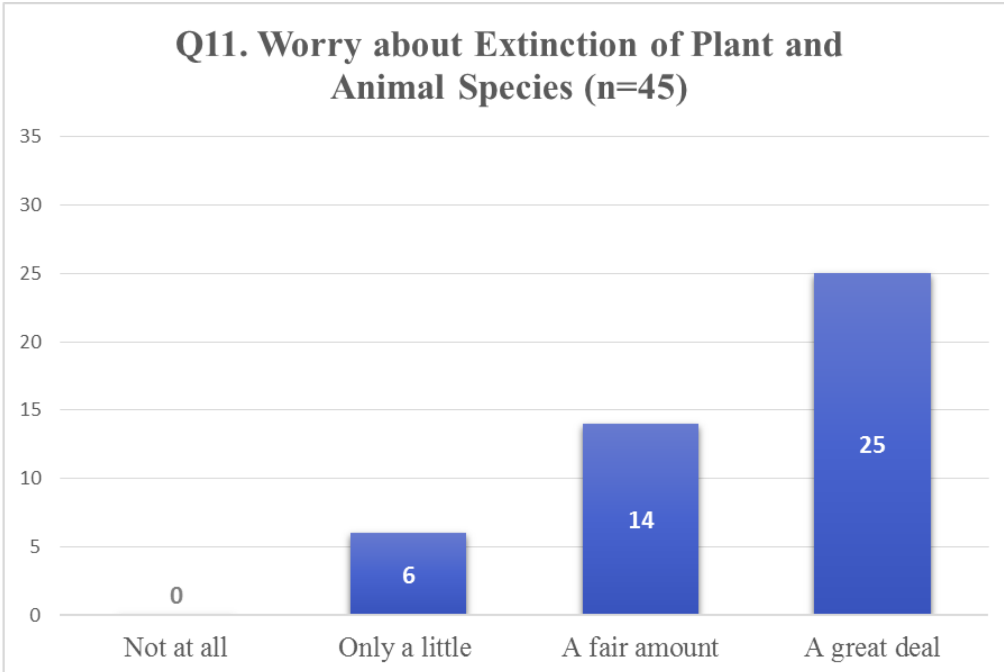
Figure 4.12 Question 11. Level of concern about various environmental issues





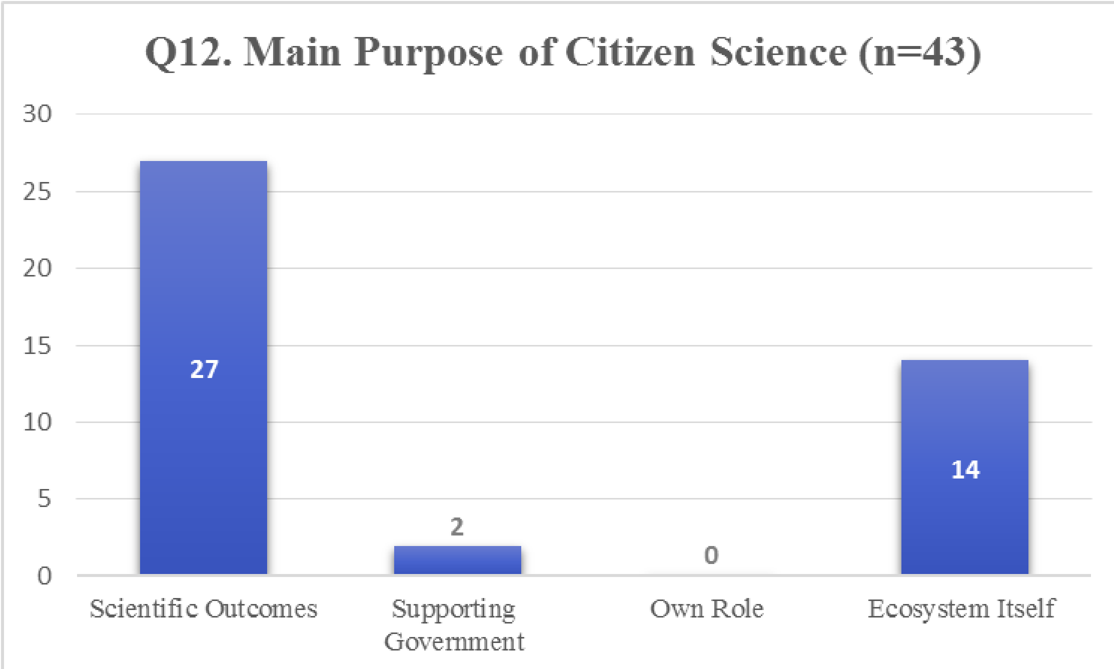

Q11. Worry about Global Warming and Climate Change (n=45)
35
30
25
20
15
10
5
0
2
5
7
31
Not at all
Only a little
A fair amount
A great deal


Q11. Worry about Air Pollution (n=45)
35
30
25
20
15
10
5
0
1
7
17
20
Not at all
Only a little
A fair amount
A great deal



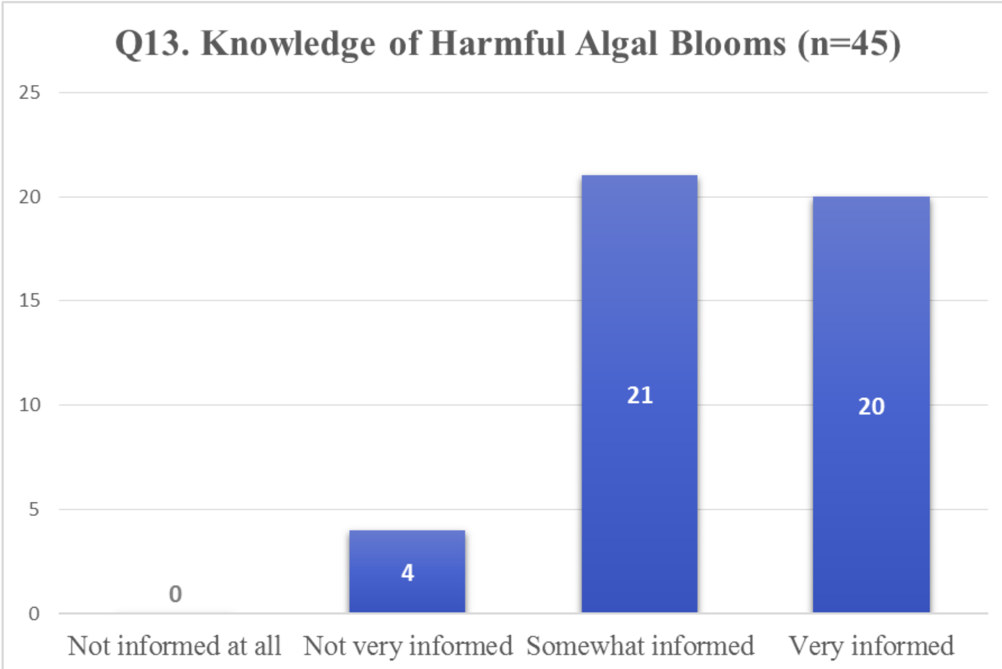
This question stated, “Below is a list of environmental problems. As you read each one, please note if you personally worry about this problem”. Respondents were asked to answer this question by circling one of four options provided on a 4-point Likert scale. The response options were: **A** ‘not at all’, **B** ‘only a little’, **C** ‘a fair amount’, and **D** ‘a great deal’, and the environmental problems included ‘pollution of drinking water’, ‘pollution of rivers, lakes and reservoirs’, ‘air pollution’, ‘global warming and climate change’, and ‘extinction of plant and animal species’. All 45 respondents circled one response option for each of the environmental problems, thus the total amount of responses for each environmental issue is 45. In respect to pollution of drinking water, three respondents (7%) said that their level of worry is ‘not at all’; three (7%) chose ‘only a little’; 14 (31%) chose ‘a fair amount’; and 25 (55%) chose ‘a great deal’. In respect to pollution of rivers, lakes and reservoirs, one respondent (2%) said that their level of worry is ‘not at all’; zero chose ‘only a little’; 12 (27%) chose ‘a fair amount’; and 32 (71%) chose ‘a great deal’. In respect to air pollution, one respondent (2%) said that their level of worry is ‘not at all’; seven (16%) chose ‘only a little’; 17 (38%) chose ‘a fair amount’; and 20 (44%) chose ‘a great deal’. In respect to global warming and climate change, two respondents (4%) said that their level of worry is ‘not at all’; five (11%) chose ‘only a little’; seven (16%) chose ‘a fair amount’; and 31 (69%) chose ‘a great deal’. In respect to extinction of plants and animal species, zero respondents said that their level of worry is “not at all”; six (13%) chose ‘only a little’; 14 (31%) chose ‘a fair amount’; and 25 (56%) chose ‘a great deal’.

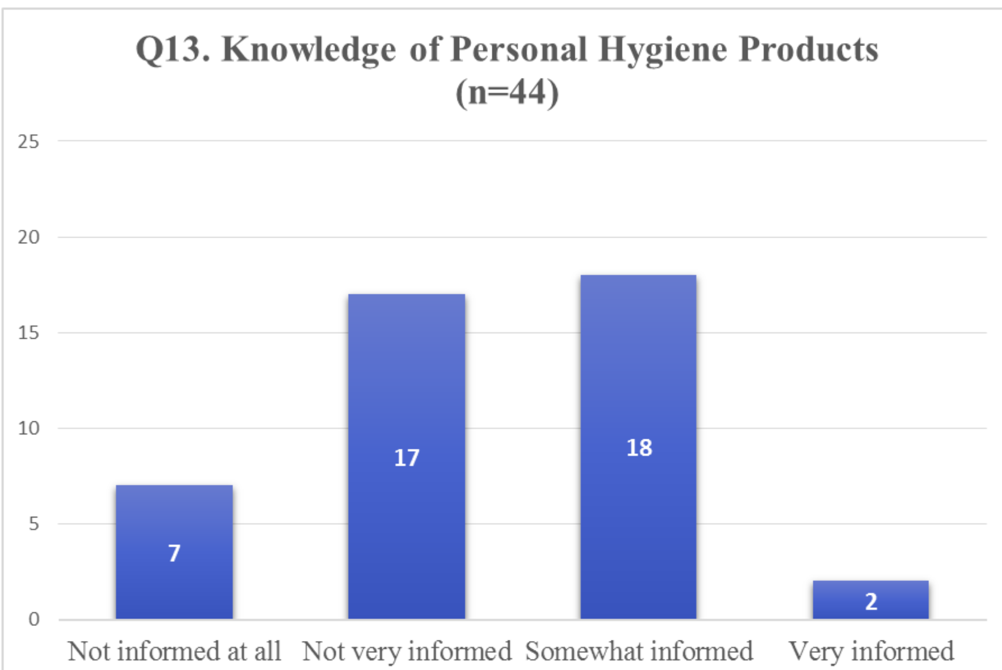
Figure 4.13 Question 12. The main purpose of citizen science

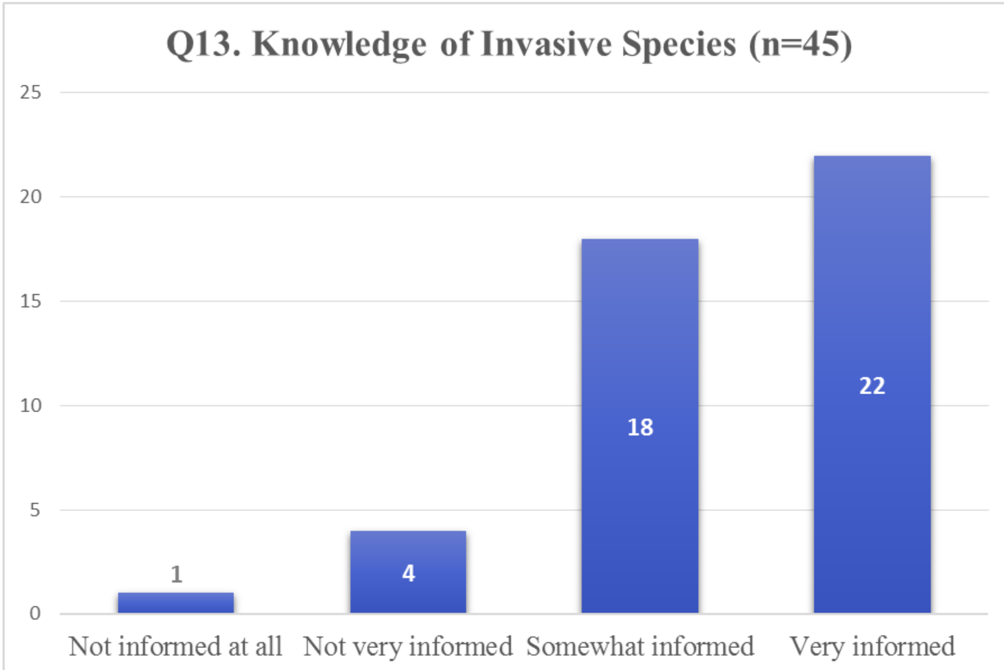


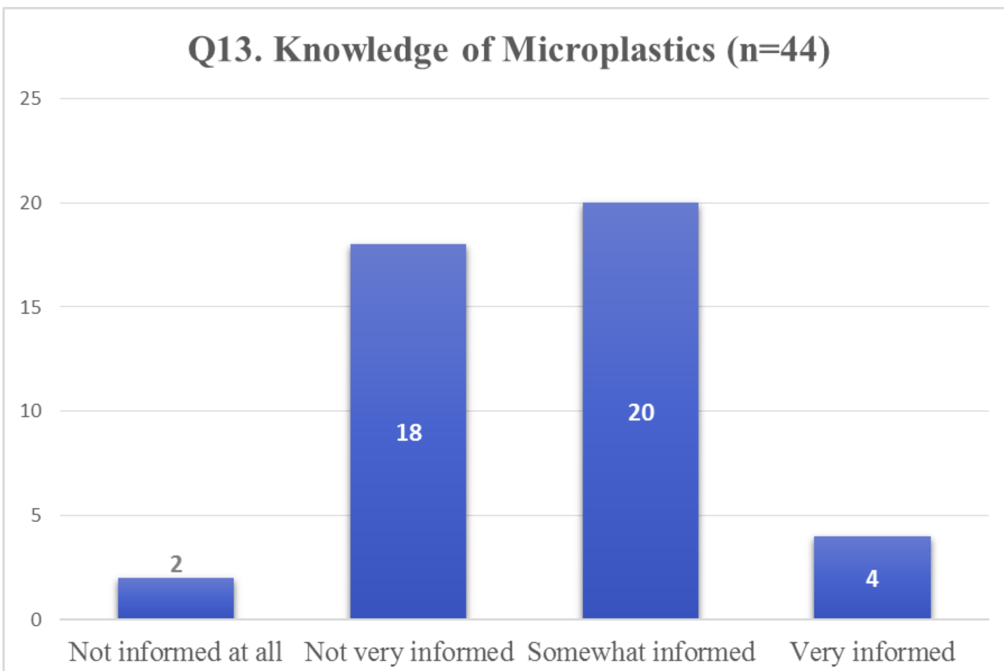
Respondents were asked to answer the question, “From your point of view, what is the main purpose of citizen science monitoring such as CSLAP (circle one)?” and were given four response options: ‘to generate data of use to science (focused on scientific outcomes)’, ‘to achieve management outcomes (focused on supporting government)’, ‘to engage in a personal interest (focused on your own role)’, and ‘to address environmental issues (focused on the ecosystem itself)’. Forty-three individuals responded to this question. Twenty-seven individuals (63%) said the main purpose is ‘to generate data of use to science (focused on scientific outcomes)’; two individuals (5%) said that the main purpose is ‘to achieve management outcomes (focused on supporting government)’; zero individuals said that the main purpose is ‘to engage in a personal interest (focused on your own role)’; and 14 individuals (32%) said that the main purpose is ‘to address environmental issues (focused on the ecosystem itself)’.

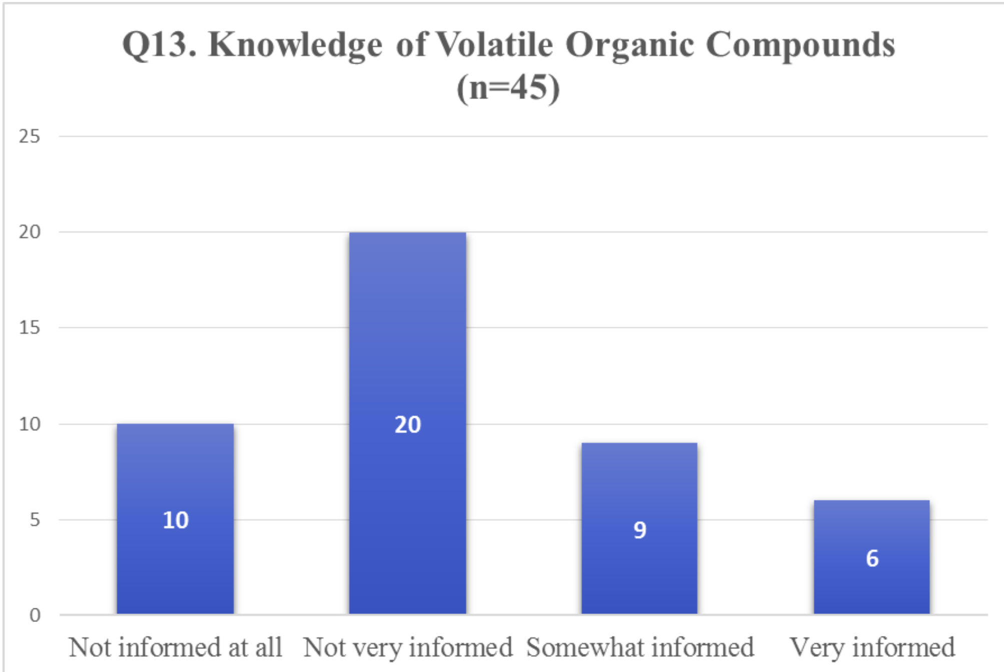
Figure 4.14 Question 13. Knowledge of various environmental topics



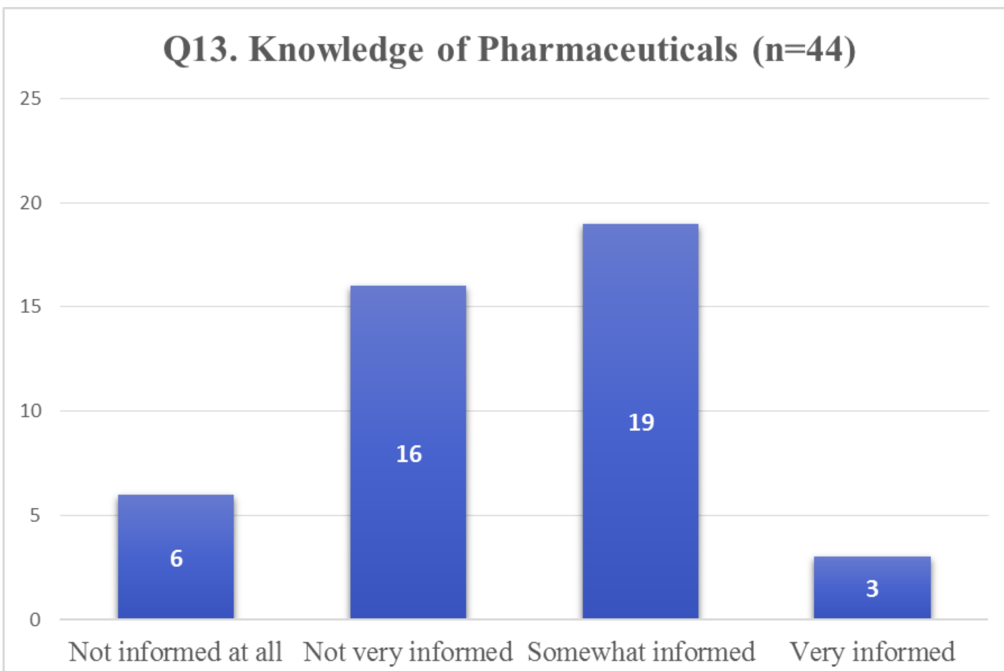



Q13. Knowledge of Invasive Species (n=45)
25
20
15
10
5
0
1
4
18
22
Not informed at all
Not very informed
Somewhat informed
Very informed

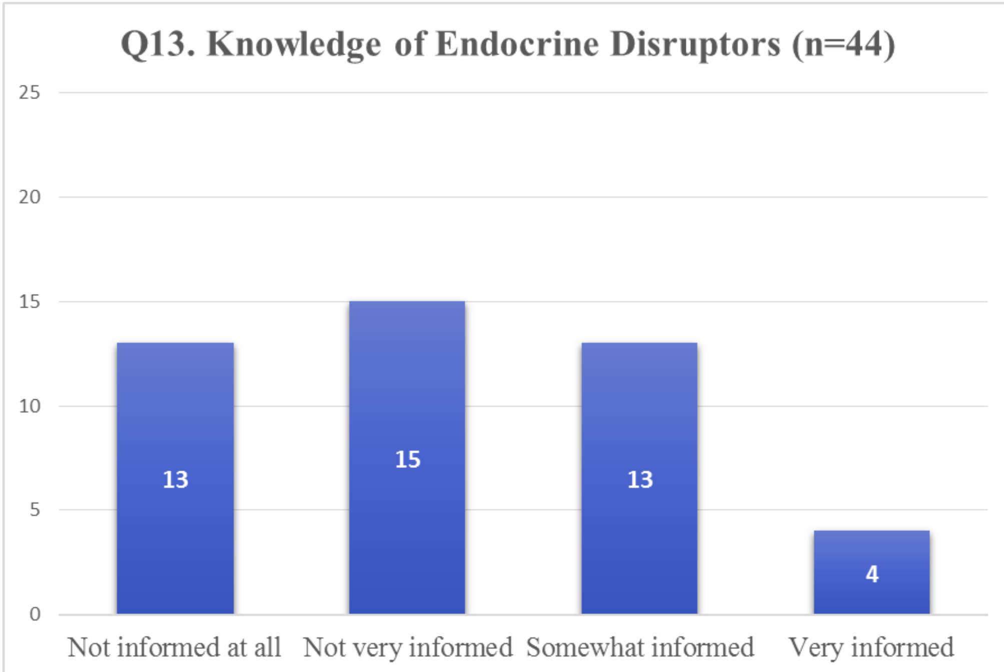

Q13. Knowledge of Microplastics (n=44)
25
20
15
10
5
0
2
18
20
4
Not informed at all
Not very informed
Somewhat informed
Very informed

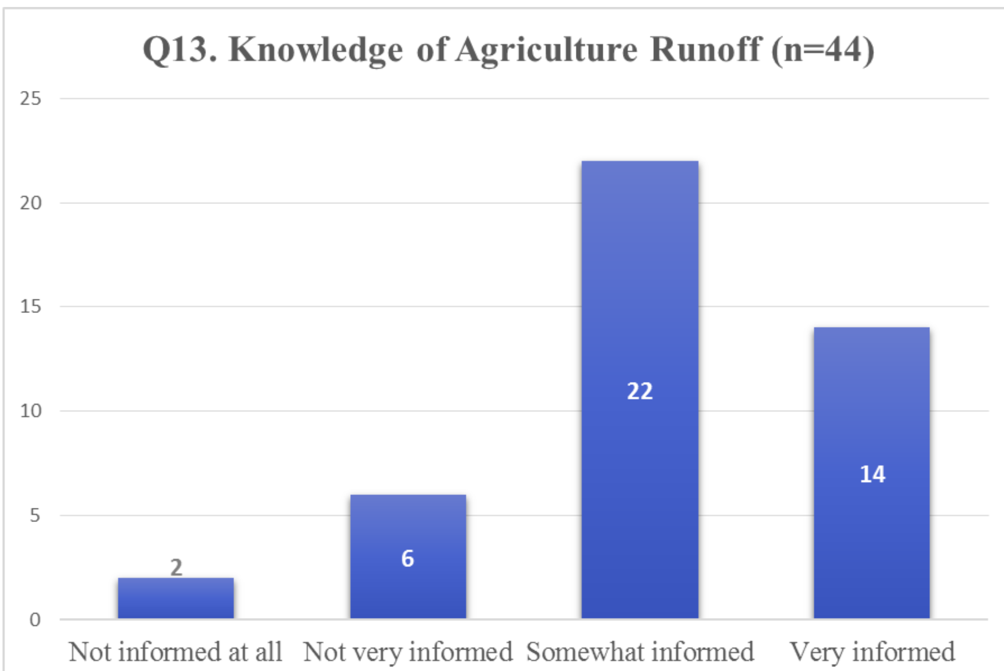


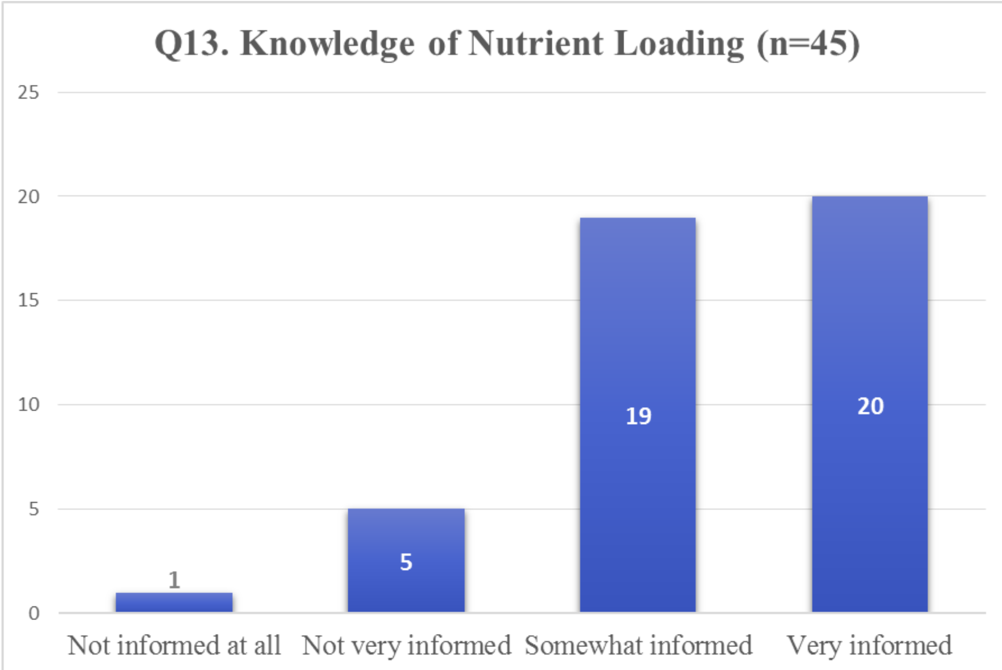
Q13. Knowledge of Volatile Organic Compounds (n=45)
25
20
15
10
5
0
10
20
9
6
Not informed at all
Not very informed
Somewhat informed
Very informed

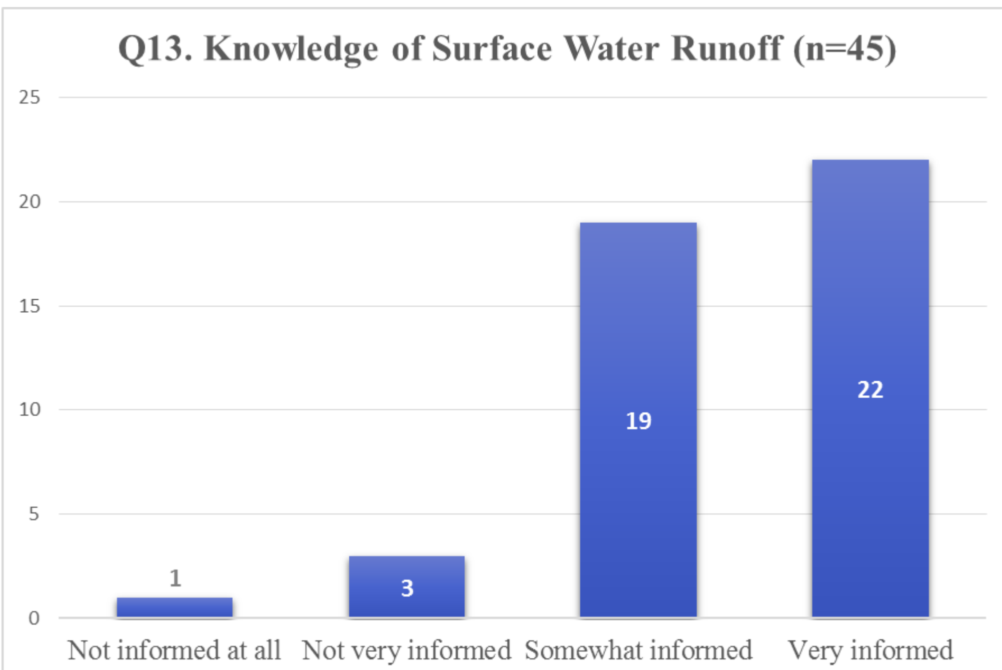


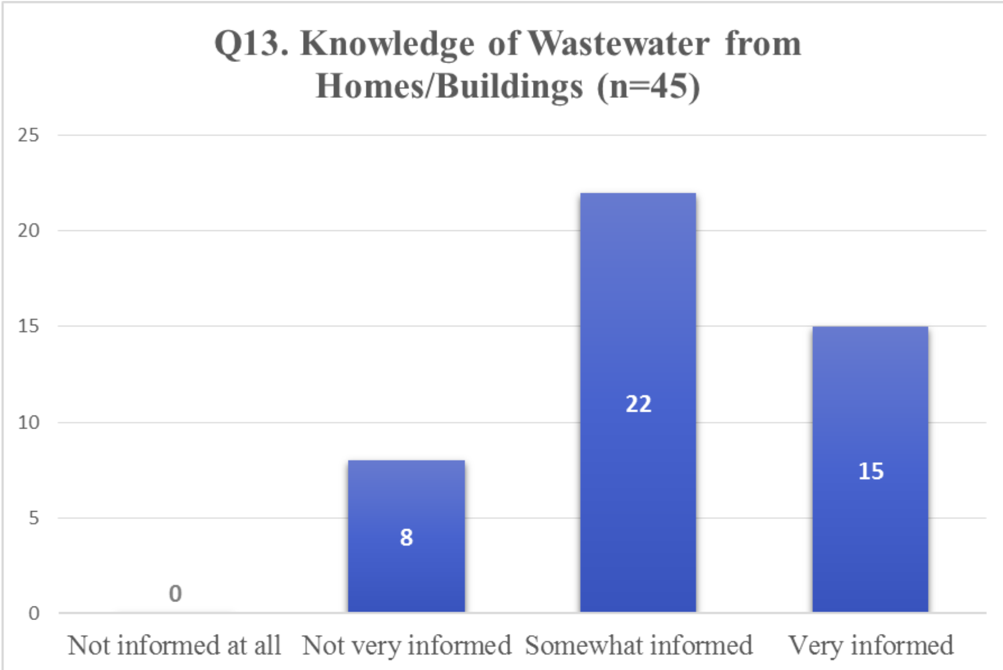
Q13. Knowledge of Pharmaceuticals (n=44)
25
20
15
10
5
0
6
16
19
3
Not informed at all
Not very informed
Somewhat informed
Very informed


Q13. Knowledge of Endocrine Disruptors (n=44)
25
20
15
10
5
0
13
15
13
4
Not informed at all
Not very informed
Somewhat informed
Very informed


Q13. Knowledge of Agriculture Runoff (n=44)
25
20
15
10
5
0
2
6
22
14
Not informed at all
Not very informed
Somewhat informed
Very informed


Q13. Knowledge of Nutrient Loading (n=45)
25
20
15
10
5
0
1
5
19
20
Not informed at all
Not very informed
Somewhat informed
Very informed


Q13. Knowledge of Surface Water Runoff (n=45)
25
20
15
10
5
0
1
3
19
22
Not informed at all
Not very informed
Somewhat informed
Very informed



Respondents were asked to reflect on how informed they think they are about different environmental concerns by answering the question, "How much do you know about the following?". Response options of: **A** 'not informed at all', **B** 'not very informed', **C** 'somewhat informed', and **D** 'very informed' were provided. The different environmental concerns asked about were: 'harmful algal blooms', 'personal hygiene products', 'invasive species', 'microplastics', 'volatile organic compounds', 'pharmaceuticals', 'endocrine disruptors', 'agricultural runoff', 'nutrient loading', 'surface water runoff', and 'wastewater from homes/building'. The descriptions for each figure are provided below.

In respect to harmful algal blooms, all 45 respondents answered the question. Zero individuals felt as though they were not informed at all; four (9%) felt as though they were not very informed; 21 (47%) felt as though they were somewhat informed; and 20 (44%) felt as though they were very informed.

In respect to personal hygiene products, 44 respondents answered the question. Seven individuals (16%) felt as though they were not informed at all; 17 (39%) felt as though they were not very informed; 18 (41%) felt as though they were somewhat informed; and two (4%) felt as though they were very informed.

In respect to invasive species, all 45 respondents answered the question. One individual (2%) felt as though they were not informed at all; four (9%) felt as though they were not very informed; 18 (40%) felt as though they were somewhat informed; and 22 (49%) felt as though they were very informed.

In respect to microplastics, 44 respondents answered the question. Two individuals (5%) felt as though they were not informed at all; 18 (41%) felt as though they were not very informed; 20 (45%) felt as though they were somewhat informed; and four (9%) felt as though they were very informed.

In respect to volatile organic compounds, all 45 respondents answered the question. Ten individuals (22%) felt as though they were not informed at all; 20 (45%) felt as though they were not very informed; nine (20%) felt as though they were somewhat informed; and six (13%) felt as though they were very informed.

In respect to pharmaceuticals, 44 respondents answered the question. Six individuals (14%) felt as though they were not informed at all; 16 (36%) felt as though they were not very informed; 19 (43%) felt as though they were somewhat informed; and three (7%) felt as though they were very informed.

In respect to endocrine disruptors, 44 respondents answered the question. Thirteen individuals (29%) felt as though they were not informed at all; 15 (33%) felt as though they were not very informed; 13 (29%) felt as though they were somewhat informed; and four (9%) felt as though they were very informed.

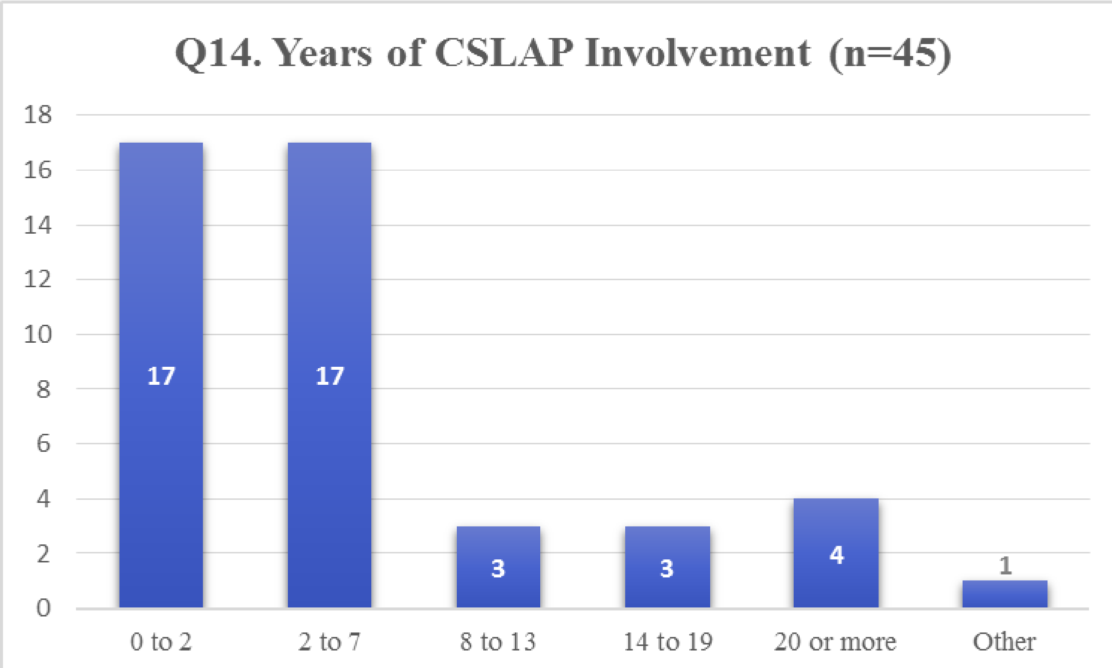
In respect to agriculture runoff, 44 respondents answered the question. Two individuals (4%) felt as though they were not informed at all; six (14%) felt as though they were not very informed; 22 (50%) felt as though they were somewhat informed; and 14 (32%) felt as though they were very informed.

In respect to nutrient loading, all 45 respondents answered the question. One individual (2%) felt as though they were not informed at all; five (11%) felt as though they were not very informed; 19 (42%) felt as though they were somewhat informed; and 20 (45%) felt as though they were very informed.

In respect to surface water runoff, all 45 respondents answered the question. One individual (2%) felt as though they were not informed at all; three (7%) felt as though they were not very informed; 19 (42%) felt as though they were somewhat informed; and 22 (49%) felt as though they were very informed.

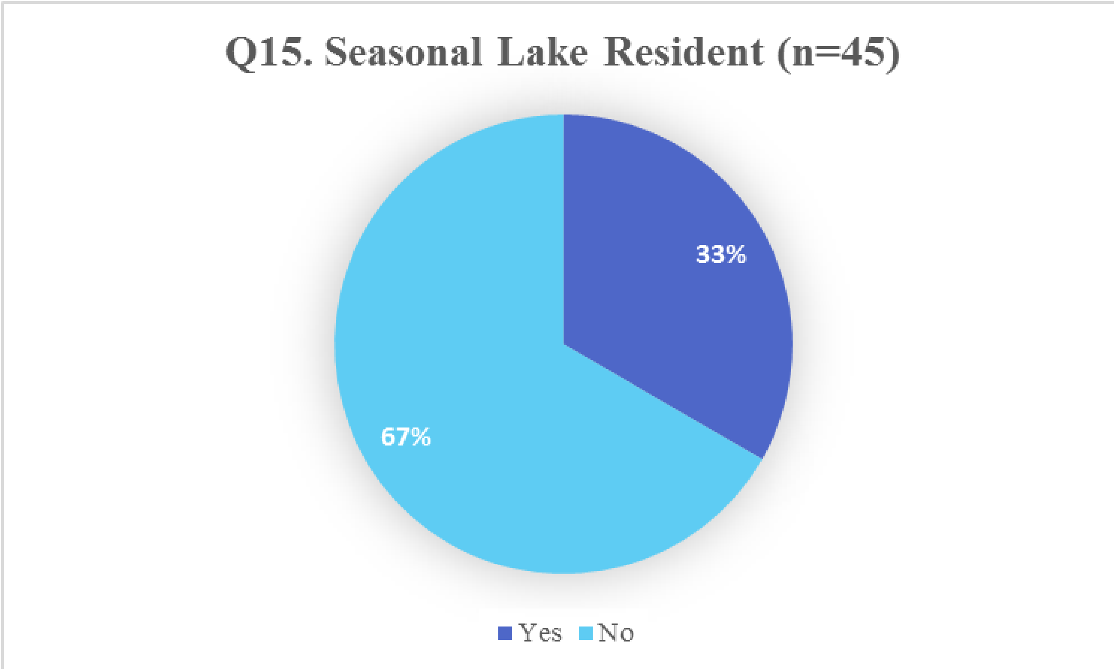
In respect to wastewater from homes/buildings, all 45 respondents answered the question. Zero individuals felt as though they were not informed at all; eight (18%) felt as though they were not very informed; 22 (49%) felt as though they were somewhat informed; and 15 (33%) felt as though they were very informed.

Figure 4.15 Question 14. Years of CSLAP involvement



Respondents were asked to answer the question, ”How many years have you been involved with CSLAP lake monitoring?” with response options of ‘0-2’years, ‘2-7’ years, ‘8-13’ years, ’14-19’ years, ’20 or more’ years, and ‘other (explain)’. All 45 respondents answered this question. Seventeen respondents (38%) said that they have been involved for ‘0-2’ years; 17 respondents (38%) said ‘2-7’ years; three respondents (6%) said ‘8-13’ years; three respondents (6%) said ‘14-19’ years; four respondents (9%) said ‘20 or more’ years; and one individual (2%) responded by choosing ‘other’, stating that he began work with CSLAP 20 years ago but had a long hiatus until this past year.

Figure 4.16 Question 15. Seasonal lake resident or not

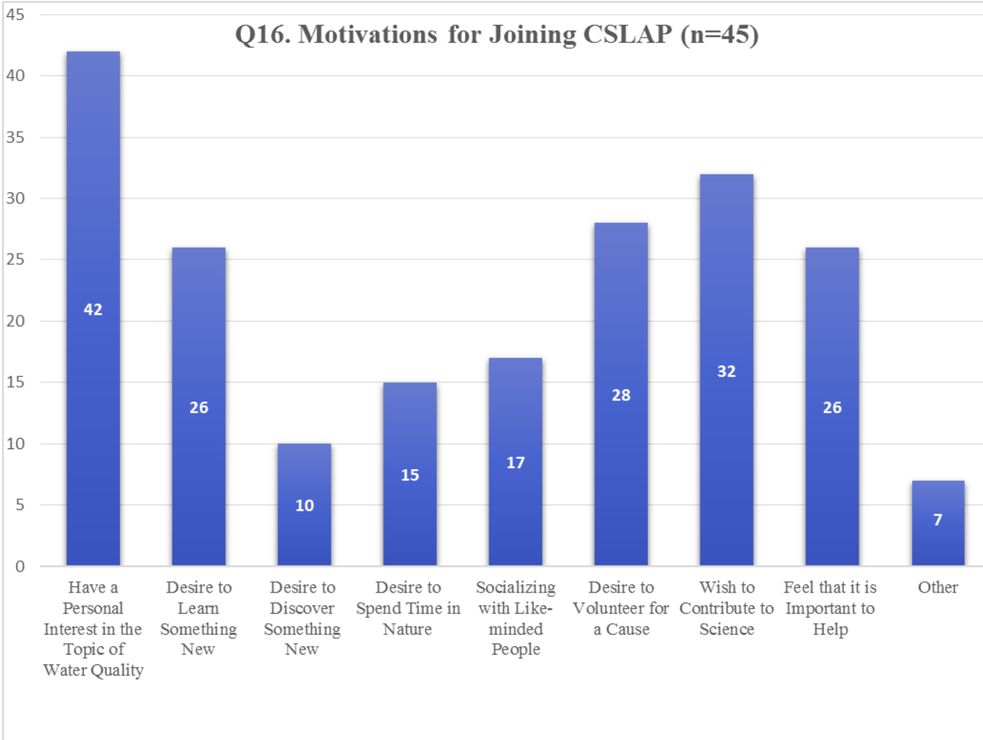


Respondents were asked to answer the question, “Are you a seasonal lake resident?” and were provided with response options of ‘yes’ and ‘no’ as well as an open ended response option that asked “if so, is your main residence close by or not? (please explain)”. All 45 respondents answered this question. 15 individuals (33%) said ‘yes’ while 30 individual (67%) said ‘no’. Twenty individuals responded to the open ended portion of this survey question and the responses are provided below.

Table 4.4 Written responses to survey question 15

Q15. Written Responses
Not... home residence in Hemington, New Jersey
Permanent lake resident
Yes, in Ithaca town
Live in Maryland but resident in Inlet, NY 3 months of the year.
Fourth Lake, Fulton Chain
Full-time lake resident
Yes, lakeside property.
Not close by. I am a resident on the lake but spend January through April in MD.
Lake is main resident
Yes
5-6 months in Florida 6-7 months at NY lake
Lake front home on Plymouth Reservoir Chenango County
6 months at Babcock Lake and 6 months a lake owned by FL community.
Snowbird = (1/2 NY + 1/2 Florida)
Main residence in lake community
Yes 30 miles away
About 1 hour away
No, 2 1/2 hour drive
137 miles away
We live on the lake year round

Figure 4.17 Question 16. Motivations for becoming a CSLAP water quality monitor

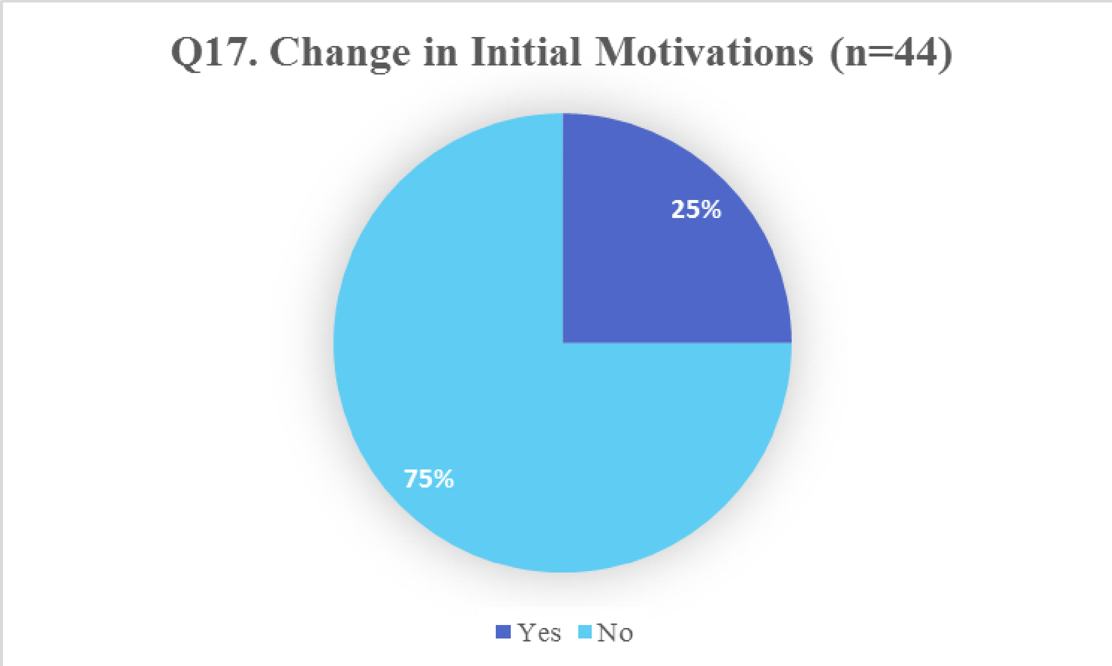


Respondents were asked to think back to their decision to become involved with volunteer monitoring and CSLAP, and answer the question, "What were your motivations (check all that apply)?" Response options provided were: 'have a personal interest in the topic of water quality', 'desire to learn something new', 'desire to discover something new', 'desire to spend time in nature', 'socializing with like-minded people', 'desire to volunteer for a cause', 'wish to contribute to science', 'feel that it is important to help', and 'other'. All 45 respondents answered this question. 42 (93%) of the 45 chose 'have a personal interest in the topic of water quality'; 26 (58%) chose 'desire to learn something new'; 10 (22%) chose 'desire to discover something new'; 15 (33%) chose 'desire to spend time in nature'; 17 (38%) chose 'socializing with like-minded people'; 28 (62%) chose 'desire to volunteer for a cause'; 32 (71%) chose 'wish to contribute to science'; 26 (58%) chose 'feel that it is important to help'; and seven (16%) chose ‘other’. Those who chose ‘other’ were provided with space to write down what their motivations were, and those responses are provided below.

Table 4.5 Written responses to survey question 16

Q16. Written Responses
For work
Make a difference in quality of lake water
Help our lake
Monitor Babcock Lake to protect water quality
It is part of my job as Property Manager
Want to be a better leader of the lake association
Love to help

Figure 4.18 Question 17. Change in initial motivations for becoming involved with CSLAP



Respondents were asked to answer the question, “Have your reasons for participating in CSLAP change over time” and were provided with response options of ‘yes’ and ‘no’, as well as an open ended response option that stated “if yes, how have they changed? In other words, please explain how your reasons for participating in CSLAP have changed over time”. Forty-four respondents answered this question, with 11 (25%) selecting ‘yes’ and 33 (75%) selecting ‘no’. 12 individuals left a response in the open-ended response section of this question and those responses are provided below.

Table 4.6 Written responses to survey question 17

Q17. Written Responses
I'm interested in exploring further opportunities in similar projects that help the finger lakes.
One can see how to use CSLAP data to improve lake quality
Paperwork + samples continue to be added
Environmental changes + changes in water (lake) quality require a greater understanding of the factors influencing that quality - with a view toward managing + improving the quality.
I find that other members of our community now expect me to have the answers. It is stressful to try to explain water testing (why?) to those who have little scientific background.
I became increasingly aware of how few people volunteer - also, in our particular situation, long time volunteers have mostly passed on. So I feel my participation is not just a good thing, it's a critical, necessary thing.
Increased awareness of the programs' importance
I think over time I've developed a sense of loyalty to DEC personnel (Scott)(Rebecca) I also realize how important it is to NYSFOLA
Every year are more thankful we joined CSLAP! - They have helped us a lot. Recognizing our problems
AIS and HABs have become very important in assessment and prevention/management in our lake.
I have renewed my interest in Environmental Science b/c of CSLAP and NYSFOLA conferences
Have learned VERY much. Have gathered MANY scientific colleagues

CHAPTER 5: DISCUSSION

One of the main findings resulting from the survey responses is that citizen scientists who participate in water quality monitoring through CSLAP have some understanding of what CECs are and where they come from, but that they can still expand their knowledge of CECs. This is not only exhibited through the responses to specific knowledge based questions on the survey, but many individuals also directly expressed interest in knowing more about CECs and the potential risks/health effects resulting from CEC exposure in an open-ended question on the survey. It was also discovered that the primary motivating factor for CSLAP volunteers' initial involvement in water quality monitoring was their interest in the topic of water quality, and that most citizen scientists in this population have not experienced a change in motivations since becoming involved with CSLAP. This discussion will go through the questions and responses that brought about these findings and will also include occasional commentary of how this survey could have been improved to make for even more impactful findings.

KNOWLEDGE AND AWARENESS OF CECS

Question 1 of this survey asked respondents to indicate if they have heard of the term 'chemicals of emerging concern (CECs)' before. While the majority of individuals responded by saying that they had heard of the term CECs before (64%), around 1/3 (36%) of individuals said that they either had not heard of the term before or were unsure if they had. This alone implies that increased education on CECs would be beneficial so that more individuals could recognize the term. Some confusion about the term 'chemicals of emerging concern (CECs)' may have originated from the lack of consistency in the terminology used to discuss CECs in the literature and media. While some sources refer to CECs as chemicals of emerging concern, other sources refer to them as contaminants of emerging concern, emerging substances of concern, compounds of emerging concern or simply emerging contaminants. While all of these terms are addressing the same groups of concerning chemicals, the lack of consistent terminology may lead to confusion amongst the public, thus it is possible that some of the individuals who said that they hadn't heard of the term 'chemicals of emerging concern' before or said that they were unsure if they had heard of CECs before may have heard of them referred to by one of the other names mentioned above. This implies that it is not only important to inform individuals of CECs, but to be sure that individuals understand that there are various terms used to discuss the same concerning chemicals.

The majority of questions on this survey, specifically Question 2, 4, 5, 6, 8, and 13, were designed and implemented to understand volunteer water quality monitors' knowledge of CECs. Most individuals, even those that answered that they had not or were unsure if they had heard of the term CECs before in Question 1, answered the following questions on the survey. This indicates that the short introduction to CECs provided at the top of the survey gave respondents enough confidence to continue answering questions on the survey. More in-depth questions gauging knowledge and awareness of CECs will now be discussed.

Question 2 asked respondents to circle which of the options provided might be considered a CEC. The most commonly selected options were human-use pharmaceuticals (89%), pesticides (82%), personal care products (78%), algal toxins (76%), and animal-use drugs (69%), all of which can contain or produce chemicals that are often categorized as CECs. These responses are promising for indicating that many people have an understanding of what CECs can be present in. About half of the respondents said that lead and arsenic are considered CECs. While lead and arsenic used to be considered CECs, both are currently regulated, thus they are typically not considered CECs. This relatively high proportion of respondents selecting lead and arsenic highlights the lack of clear and straightforward information provided to the public about these chemicals; while some sources, including the EPA, state that CECs are chemicals or materials that are not currently regulated (OW/ORD Emerging Contaminants Workgroup, 2008; Task Force on Emerging Contaminants, 2018), others do not stipulate that the lack of regulations is a determining factor on whether a chemical is considered a CEC ("Contaminants of Emerging Concern," n.d.; U.S. Geological Survey, n.d.).

While the responses to this question highlight that many individuals know what CECs can be present in, a more accurate way to have asked Question 2 would have been to ask which of the options below have the *potential* to *contain* CECs because the options provided are not inherently CECs as CECs are the concerning chemicals inside of the product, not the entire product itself. Pharmaceuticals and personal care products are not entirely made of CECs, and products in these categories may not contain any CECs. Thus it is incorrect to claim, for example, that all shampoos or makeup, common types of personal care products, contain CECs. Sources such as the EPA even refer to pharmaceuticals and personal care products as CECs rather than referring to the chemicals that may be present in some of them, which is problematic (U.S. Environmental Protection Agency, n.d.-a). For people to have a better understanding of what CECs are and what products they are in, the information shared about CECs needs to be both accurate and consistent.

Question 4 asked respondents what the primary sources of CECs are in natural waterbodies, and response options included sewage treatment plants, septic systems, industrial and manufacturing facilities, residential households, crop fields, and poultry farms and animal feeding facilities. Respondents chose multiple locations as primary sources of CECs, meaning that they understand that these chemicals come from a variety of sources/locations, which is important as this is part of what makes CECs so difficult to study, understand, and remove from the environment. The most selected option was septic systems (87%) and the least selected option was industrial and manufacturing facilities (66%). Seventy-seven percent of respondents selected residential households, 75% selected sewage treatment plants, 70% selected crop fields, and 68% selected poultry farms and animal feeding facilities.

Since the two most frequent responses to Question 4 were septic systems and residential households, it seems that most respondents understand humans' role in CECs introduction to the environment. The majority of respondents appear to understand that sewage treatment plants do not remove all chemicals from bodily waste during the treatment process because many individuals selected sewage treatment plants as a source of CECs in natural waterbodies. Many individuals also appear to understand that CECs can end up in natural waterbodies after product use in agriculture and livestock raising. Interestingly, the fewest amount of people selected industrial and manufacturing facilities as a primary source of CECs into natural waterbodies, even though the majority of products used in households and agricultural practices are created at these facilities. These results taken altogether may imply that while individuals feel responsible for the use and dispersal of CECs into the environment, they overlook the fact that many chemicals originate and are released into the environment by industrial and manufacturing facilities, and this could lend valuable insight into future campaigns for both public education and policy implementation. If individuals wish to reduce CECs accrual, they can seek out products with less potentially harmful chemicals and they can also advocate for stricter regulations on manufacturing plants which introduce CECs into waterbodies. Future advocacy campaigns can also highlight that if CECs are not produced or mixed into personal goods, citizens will not have to worry about introducing them into the environment through their septic and sewage systems.

While the responses to Question 4 helped to highlight what individuals know about where CECs come from, some improvements to the question and the response options would have been beneficial. One improvement would be to remove the word ‘primary’ from the question, as they arrive in waterbodies through many different uses and pathways and the word ‘primary’ may have deterred individuals from selecting multiple options. Another improvement would have been to remove the response options of sewage treatment plants and septic systems as their presence causes overlap in the response options. Sewage treatment plants and septic systems are often utilized to treat wastewater coming from places such as industrial and manufacturing facilities and residential households, thus sewage treatment plants and septic systems should not have been included in the response options for this question. Although quite challenging to do, it also would have been beneficial to define what is meant by ‘source’ in this question. Considering that CECs often move from industrial and manufacturing facilities to households, and then to septic systems and sewage treatment plants, the official ‘source’ of a CEC is difficult to determine. An added complication to discussing the sources of CECs is that chemicals can interact and with other chemicals in different scenarios to form transformation products (Bilal et al., 2019), so discovering where a CEC originates from can be extremely complicated. Although these improvements would have benefitted the clarity of and responses to this question, seeing that many individuals chose multiple sources out of the options listed shows that they understand that these chemicals come from a variety of sources/locations.

Question 5 and Question 6 of this survey asked respondents whether or not they know about the presence of laws and policies regarding CECs in water in both New York State alone and any other U.S. states, respectively. The majority of responses for both questions was ‘not sure’ rather than ‘yes’ or ‘no’. As defined by the EPA, CECs are chemicals that have no regulatory standard (OW/ORD Emerging Contaminants Workgroup, 2008), meaning that there are technically no laws or policies on current CECs in the United States. Once CECs become regulated, they are typically no longer considered CECs as this terminology is reserved for chemicals or substances that are not regulated. This makes it challenging to answer this question, as previous CECs may be regulated, but they are often not considered CECs anymore following regulation. Thus, it makes sense that many individuals said that they were not sure if there are any laws or policies regarding CECs.

Many individuals showed interested in increasing their knowledge and understanding of CECs. Question 8 of this survey asked respondents if they have any questions regarding CECs or this study, and asked for respondents to write down their questions. With open-ended responses such as, “Since I am unaware of any CECs, I need to learn about all of them,” “impacts on water quality [and] human health”, and “many, but mainly… is there any immediate risk to swimming or recreational contact with CECs”, it is apparent that people are curious and/or concerned about CECs and want to better understand them and their impacts. This desire to learn more about CECs is extremely promising because informing people of CECs and their impacts is an important step towards addressing the issues associated with CECs.

Question 13 asked participants to indicate how informed they think they are about a variety of environmental topics. To better analyze and discuss the results, the responses of ‘not informed at all’ and ‘not very informed’ were grouped together, as were the responses of ‘somewhat informed’ and ‘very informed’, to obtain two categories of knowing less or knowing more about each environmental issues.

Table 5.1 includes the combined number of responses for these categories. Of the different issues, respondents felt the most informed about surface water runoff, harmful algal blooms, invasive species, agriculture runoff, nutrient loading, and wastewater from homes/building. Much of CSLAP monitoring focusses on invasive species, nutrient loading, and harmful algal blooms (New York State Department of Environmental Conservation, n.d.-b), so it is understandable that individuals felt as though they knew more about these topics than some of the others listed. These are also more established topics in water quality literature, whereas the topic of CECs is relatively new in comparison. Respondents felt as though they knew less about microplastics, pharmaceuticals, and personal hygiene products than the other issues mentioned above, and they felt that they were least informed about volatile organic compounds and endocrine disruptors. Most respondents felt either somewhat or very informed about wastewater from homes/buildings, but considering that they said that they knew less about pharmaceuticals and personal hygiene products, it is possible that they do not understand wastewater as well as they may think that they do. The responses to this question highlight the potential to inform more individuals about CECs because while individuals associated with CSLAP believe that they have a higher level of knowledge about topics such as HABs, runoff, and nutrient loading, they admittedly do not know as much about pharmaceuticals, personal care products, and other potential CECs/sources.

Table 5.1 Combined responses for level of knowledge from survey question 13

Environmental Topic	**Not at all informed (A) / Not very informed (B)**	**Somewhat informed (C) / very informed (D)**
Harmful Algal Blooms	4	41
Personal Hygiene Products	24	20
Invasive Species	5	40
Microplastics	20	24
Volatile Organic Compounds	30	15
Pharmaceuticals	22	22
Endocrine Disruptors	28	17
Agriculture Runoff	8	36
Nutrient Loading	6	39
Surface Water Runoff	4	41
Wastewater from Homes/Buildings	8	37

A concern with this question is that it does not ask respondents to answer the questions based on their knowledge of these environmental topics in association with water quality but instead simply asks respondents to answer the question, “how much do you know about the following?”. It is possible that respondents assumed that this question was referring to water quality because the rest of the survey is focused on this topic, but it is also possible that respondents thought that they should answer the question based on their overall knowledge about each topic, not specifically for their level of concern in respect to water quality. For example, part of this question asks individuals about their knowledge of pharmaceuticals and personal hygiene products, but since the question was not explicitly asking individuals to respond with what they know about these products in water, answers may not reflect what the question was intended for. While this question should have been asked in a clearer manner, there are still interesting results, as discussed above, based on the responses for the different environmental topics asked about and the lack of clarity does not negate these results.

KNOWLEDGE OF WASTEWATER

Question 9 and Question 10 of this survey were implemented to better understand the knowledge that respondents have about wastewater, particularly septic systems and straight pipes. Question 9 asked if septic systems require regular maintenance and if so, how frequently, and Question 10 asked if participants have heard of the term 'straight pipe' and if so, what it is. Most respondents (93%) said that septic systems do require regular maintenance. This is a positive finding in that the vast majority of respondents confirmed that regular maintenance was necessary, which reflects accurate knowledge about septic system maintenance. A variety of answers were provided regarding how frequently maintenance is required, which is understandable due to the different factors that affect maintenance frequency such as household size, total wastewater generated, volume of solids in wastewater, and the septic tank size (U.S. Environmental Protection Agency, n.d.-c). While these different factors affect maintenance frequency, the EPA states that the average household septic system should be inspected by a professional at least every three years and that pumping is typically required every three to five years (U.S. Environmental Protection Agency, n.d.-c). Many individuals responded by stating that "it depends" while others responded with a range of one to six years. While a few individuals noted that they were unsure of how often maintenance is required on septic systems, the majority of respondents wrote down a specific amount of time, which may imply that they do know how often their septic system at home requires maintenance, or have simply heard how often one should care for their septic system.

When asked about their knowledge of straight pipes in Question 10, more respondents said that they had not heard of the term 'straight pipe' (57%) than those who said that they had (43%). The ambiguity of this question may have played a role in the responses as the term 'straight pipe' could be referring to many different things, not just wastewater transfer, but all 18 individuals who further explained what a straight pipe is were correct or on the right track. The responses to this question highlight that while those who have heard of a straight pipe before know what a straight pipe is, there are many who have not heard of the term before and may not know what a straight pipe is and the environmental impacts of them. A straight pipe is a pipe that transfers wastewater directly from a home into a waterbody due to a lack of a sewage system or septic tank (Phelps, 2013). This wastewater can originate from showers, sinks, or washing machines, and it can also originate from toilets, meaning that raw sewage is transported directly into nearby waterbodies. These pipes allow chemicals and bacteria to enter waterbodies prior to any form of treatment, which can harm humans, animals, and plants (Phelps, 2013). It is important for people to understand what straight pipes are and to recognize that the chemicals that they use in their homes can flow directly into waterbodies and can impact ecosystems and human health.

MOTIVATIONS OF CITIZEN SCIENTISTS

Individuals who choose to volunteer with citizen science projects tend to have complex motivations for doing so, and understanding their motivations for participating is critical to both the initial development and long-term success of citizen science projects (Alender, 2016). Thus this survey asked CSLAP volunteers to answer two direct questions regarding their motivations for participating in water quality monitoring. The first question asked what initially motivated them to become involved with CSLAP monitoring (Question 16), and the second asked if their motivations for participating had changed over time (Question 17). Question 16 asked participants to check all that apply in respect to their different motivations, while question 17 included response options of 'yes' and 'no', with an open-ended follow-up portion that requested that if an individual said that their motivations did change over time, that they indicate how their motivations changed. Relatively little research has been done that looks into what motivates individuals to participate in citizen science projects; however, the research that has been done has shown that, 1) motivations vary immensely between different people, 2) that there are often multiple motivations involved at any one time, and 3) that motivational factors are complex, involving both altruistic and self-directed motives (Alender, 2016; Clary et al., 1998; Kragh, 2016).

While most volunteers have both self-directed and altruistic motives for participating in citizen science initiatives, the strongest motivators for voluntary citizen science involvement found in previous studies tend to be altruistic factors such as helping the environment and/or contributing to innovative scientific research (Alender, 2016; Brouwer et al., 2018; Kragh, 2016). However, in this study, the highest chosen initial motivator for those involved with

CSLAP water quality monitoring was having a ‘personal interest in the topic of water quality’, which is a self-directed motive rather than an altruistic motive. Forty-two individuals said that one of their initial motivations for becoming involved with CSLAP monitoring was based on a personal interest in the topic of water quality, while 32 individuals said that they wanted to contribute to science, 28 individuals said that they had a desire to volunteer for a cause, 26 individuals said that they felt as though it was important to help, and 26 individuals said that they had a desire to learn something new. Wanting to contribute to science, having a desire to volunteer for a cause, and feeling as though it is important to help are all altruistic motives. The least chosen motivational factors included socializing with like-minded people (38%), the desire to spend time in nature (33%), and the desire to discover something new (22%), which are all self-directed motives. Multiple individuals also noted in the ‘other’ open-ended option that they have a desire to keep specific lakes healthy, which are likely lakes that those individuals live on or rely on for recreation. This type of response is both self-directed and altruistic as individuals personally gain from keeping their lake healthy and they are also helping others and the environment by participating. It can be seen that while the self-directed motive of having a personal interest in the topic of water quality was the highest chosen option by participants, following that option, altruistic motives were chosen by more individuals than self-directed motives were.

These results support the findings from other citizen science literature that shows that individuals have many different reasons for becoming involved with citizen science projects and that both personal and altruistic motives tend to be involved in one’s decision to participate, but differ from the research that shows that altruistic motives tend to be more important than self-directed motives, as the highest chosen motivational factor in this study is a self-directed motive.

While Kragh (2016), states that meeting the altruistic motivation of volunteers is key to retaining those volunteers, the present study shows the need for citizen science project coordinators to look into the self-directed motives of individuals and recruit those who are interested in the specific topic that their project is directed towards.

The Volunteer Functions Inventory was developed by Clary et al. (1998), and includes six categories associated with the motivations behind citizen science volunteerism, the six categories being ‘understanding,’ ‘values,’ ‘social,’ ‘protective,’ ‘enhancement,’ and ‘career.’ ‘Understanding’ refers to a desire to learn and share knowledge; ‘values’ refers to altruistic concern for others, the environment, and/or science as a whole; ‘social’ refers to meeting new people and strengthening relationships; ‘protective’ refers to reducing negative feelings about one’s self; ‘enhancement’ refers to personal growth and development, and; ‘career’ refers to the hope that gaining experience in a field by volunteering will benefit one’s career in the future (Alender, 2016; Buytaert et al., 2014; Clary et al., 1998; West & Pateman, 2016). The ‘understanding’, ‘values’, and ‘social’ categories were researched more in this study than the ‘protective’, ‘enhancement’, and ‘career’ categories as the response options provided in question 16 focused on learning or discovering new things, contributing to and helping the environment, and socializing. The ‘protective’ and ‘enhancement’ categories may have played a role in the feelings of those who chose the ‘desire to spend time in nature’ as a motivator for participation and could have also influenced other chosen options, such as the ‘desire to volunteer for a cause’ and/or the feeling that ‘it is important to help’, but further research would be needed to corroborate this hypothesis. The ‘career’ category was not specifically highlighted in this survey. It could have been beneficial to have a career oriented response option included in question 16 because research has shown that younger individuals tend to care more about the career benefits of citizen science volunteerism than older individuals (Alender, 2016). Although the majority of volunteers who participate in CSLAP and who took this survey are older individuals who are established in their career or retired, this question specifically asked what initially motivated participants to become involved in water quality monitoring, thus there could have been some interesting career oriented results, particularly with the individuals who have been volunteering for CSLAP for many years.

Participants' motivations were further understood through Question 17 of this survey which asked if participant's motivations had changed over time. Only 11 individuals noted that their motivations had changed over time, while 33 individuals said that their motivations for participating in CSLAP had not changed. Those who said that their motivations did change over time mostly expressed the sentiment that their work for CSLAP and the NYSDEC feels important and necessary. One individual in particular responded that they felt as though their "participation is not just a good thing, it's a critical, necessary thing" and another wrote that they have an "increased awareness of the programs' importance." Others mentioned social factors such as "gather[ing] MANY scientific colleagues" and "develop[ing] a sense of loyalty to DEC personnel" as reasons for their motivational change over time.

The majority of individuals responded 'no' to Question 17, thus it can be seen that initial motivations tend to persist even after many years of involvement and that future motivations can be strongly related to initial motivations. When analyzing Question 16 and Question 17 together, it appears that finding individuals who are motivated to volunteer in citizen science projects due to an interest in the topic of the research itself can be important for both initial and prolonged involvement. While these findings are important, it must also be noted that the individuals who responded to this survey paid to attend the NYSFOLA conference, which focusses on different topics associated with water quality, thus many of these individuals are very interested in the topic of water quality which could differ from others within CSLAP. Although outside the scope of the present work, a study that examines what caused prior volunteers to quit the program would also be a valuable add-on to this project, as learning what factors can lead to quitting is just as valuable to citizen science program organizers as knowing which factors attract new people and retain those individuals. More research should be completed to better understand how motivational factors change over time for citizen science volunteers, but this research shows that for this group, most individuals are still motivated by the factors which motivated them to become involved in the first place.

Question 11 of this survey asked respondents to note how much they worry about a variety of environmental problems, including pollution of drinking water, pollution of rivers, lakes, and reservoirs, global warming and climate change, air pollution, and extinction of plant and animal species. For four of the five problems, 55% or more indicated that they worry about each of them a great deal. Many of those who did not say that they worry a great deal said that they worry a fair amount, and a smaller number of individuals said that they worry only a little or not at all about each of the issues. Respondents appear to be the most worried about pollution of rivers, lakes, and reservoirs, with their concerns about global warming and climate change following closely behind.

The concern that these individuals have for the health of rivers, lakes, and reservoirs may be related to their motivations behind their initial and continued involvement with CSLAP. Taking into consideration that the majority of individuals indicated in Question 16 that they became involved with CSLAP monitoring due to an interest in the topic of water quality, it is understandable that these individuals may have greater concern over the health of rivers, lakes, and reservoirs. CSLAP participants may have become involved with water quality monitoring because they had preceding concerns about the health of waterbodies, or they may have become worried about water quality issues after becoming involved with CSLAP monitoring and learning about the issues through hands-on experience. Further research looking into the relationship between environmental concerns and citizen science projects could help to strengthen the field of citizen science as those who are more worried about certain issues may be more interested in becoming involved with projects that focus on those issues, and/or individuals may become more educated about environmental concerns through their involvement in citizen science projects.

It can be concluded from the responses to these questions that motivations differ for individuals and that what initially motivates an individual to volunteer with a citizen science project can motivate them to remain involved for the long-term, but there is potential for motivations to change over time as well. Motivations are often both self-directed and altruistic, and individuals are often motivated by a number of factors which may differ depending on the project. Thus, citizen science project coordinators should look to better understand the motivations behind volunteer involvement in their specific programs. Initial recruitment and retention rates are highly dependent on how motivated individuals are to complete the necessary work and may also be greatly influenced by the level of interest/concern that individuals have for the topic of the citizen science project. Any further examination into the motivations of citizen science volunteerism would be beneficial for citizen science recruitment and retention processes.

PURPOSE OF CITIZEN SCIENCE

To better understand what volunteers thought about the purpose of their involvement with CSLAP water quality monitoring, Question 12 of this survey asked respondents to circle one of four choices responding to the question, “From your point of view, what is the main purpose of citizen science monitoring such as CSLAP?”. The majority of respondents (63%) chose ‘to generate data, of use to science’ while zero respondents chose ‘to engage in a personal interest’, meaning that those who choose to donate their time and energy to citizen science projects, while they may gain some enjoyment out of the process, tend to find the scientific outcomes of projects to be more important than satisfying their own personal interests. While results from question 16 referring to motivations showed that many people became involved with volunteer monitoring due to a personal interest in the topic of water quality, Question 12 shows that they believe that their personal interest in the topic is not the main purpose of citizen science as a whole. While an interest in the topic and wishing to generate data of use to science are not mutually exclusive, these results taken together may mean that while these volunteers initially became involved due to their personal interest, they learned over time that there are more important reasons for their participation that go beyond personal satisfaction and enjoyment.

Interestingly, only two individuals responded that the main purpose of citizen science monitoring is “to achieve management outcomes (focused on supporting government)”. Research has shown that data collected by citizen scientists can often be questioned by those in decision-making or policy positions due to potential biases or inaccuracies of data (Alender, 2016; Heigl, Kieslinger, Paul, Uhlik, & Dörler, 2019). If data were more commonly utilized in decision-making and policy implementation, it is possible that more individuals would see this as being the main purpose of citizen science research as it goes further than just collecting the data for scientific purposes. While the act of collecting data for scientific purposes alone is extremely important, that data must be further utilized to reach its full potential. In this respect, it would be greatly beneficial for citizen science initiatives to be utilized for not only gathering data, but also implementing change through policy and decision making.

While the option ‘to address environmental issues (focused on the ecosystem itself)’ was the second most chosen option with 14 people (32%) selecting it as the main purpose for citizen science, the same thought as above applies here. It is possible that more individuals would select this option if they saw environmental issues brought about by their data collection being addressed more often. This is not to say that citizen science data is not being used to address environmental issues or management outcomes, but if these outcomes were greater emphasized within citizen science projects rather than simply the data collection aspect, it is possible that more individuals would have chosen this response option. The lack of further use of volunteer collected data is an inherent issue within citizen science projects and more thought and effort should be put into utilizing the data that has been collected. As discussed within the literature review, there are many reasons why citizen science data is not used to its full potential, particularly due to inaccuracies and/or biases, thus project coordinators should look to improve citizen science data collection accuracy as well as reduce biases so that more can be done with the data that is being collected by dedicated volunteers. As stated by Heigl et al. (2019), “Let’s make sure that future [citizen science] projects have sufficient rigor to earn the respect of participants, scientists, and policymakers”. Only then will we begin to see citizen science data being further utilized to its full potential.

CHAPTER 6: CONCLUSIONS

This research has presented important information regarding the knowledge and awareness that citizen scientists have of CECs as well as the motivations behind their involvement in water quality monitoring. While some individuals are aware and have some knowledge about CECs, there is opportunity for more information to be shared with CSLAP participants about what CECs are, where they come from, and what impacts they have on human health and the environment. Sharing more information about CECs would lead to a more informed public, and potentially more research and action on CECs. There is also potential to increase CECs research within citizen science projects, whereby citizen scientists could work with researchers and policymakers to tackle the issues that many CECs pose. Considering that many of these individuals became involved with water quality monitoring due to an interest in the topic of water quality, it is highly possible that numerous volunteers would happily welcome new opportunities that include CECs research, and future citizen science project coordinators should certainly seek out local water quality monitoring organizations to recruit volunteers.

The terminology for and definition of CECs needs to be more consistent among different sources, as the confusion that arises due to the differing names and defining characteristics of CECs must be addressed before clear and straightforward information can be provided to others about these concerning chemicals. The general public should be better informed about CECs, but information dissemination can be very challenging to do with ill-defined and complex topics, thus clarifying what these chemicals are is the first step to better informing people of them. Rather than having multiple different terms to refer to these chemicals, the scientific community and the public would benefit from more consistency in the terminology and definition of them.

CECs are an extremely complicated and evolving subject, thus to clarify information on them, which is extremely important, more research needs to be done to better understand them and their impacts. Large amounts of chemicals are being released into the environment each day and researchers do not know what impacts many of these chemicals have on the environment and on human health. CECs are technically unregulated substances, and without further information being discovered about CECs, regulation will continue to be at a standstill. It is necessary for more funds to be dedicated to CECs research and for the public to become more aware of the potential issues that CECs have for the health of the environment as well as human health. Additionally, consumers can be motivated to take action to become more informed about what is in the products that they purchase once they better understand the treats and hazards associated with CECs.

While there is still much to be done to characterize and regulate CECs, citizen science provides a valuable route for research and action. Research and information dissemination leads to increased knowledge and awareness, and citizen involvement in CECs research can lead to an enhanced sense of stewardship which can then empower individuals to take further action against CECs as a form of democratic participation that regulatory structures often depend on. To better inform the public of this research and of CECs, an informative website was created utilizing Dreamhost software and published in the summer of 2019. This can be viewed in Appendix E.

As said by Rachel Carson (1962) in her book *Silent Spring*, “Only within the moment of time represented by the present century has one species -- man – acquired significant power to alter the nature of the world”. CECs alter the nature of the world, and it is necessary for humans to take action to address the problems which they have created and contributed to.

FUTURE DIRECTIONS

There are multiple suggestions for future research endeavors that stem from this study. One suggestion would be to do an analysis of what the general public knows and understands about CECs. The specific study population of this research (CSLAP participants) is a niche population within New York State, and it is important to understand what knowledge and awareness the general public has about CECs as well. This includes where they originate from, what the risks associated with them are, and what to do about them. By specifically looking for gaps in knowledge, the public can then be better informed about CECs through education and outreach initiatives which could lead to further action directed at CECs.

To better understand what the public knows about CECs and to learn how to inform individuals of CECs through education and outreach, clarifying the term CECs in the literature and media is extremely important. To do this, an in-depth analysis of the term 'CECs' and other similar terms is required, and the scientific community should decide if CECs is the best possible term to use when referring these chemicals or if another term would be more appropriate. There are many other terms that are used to characterize these chemicals, thus clarification is needed. There is also a great need for more research to be completed to better understand the impacts that different CECs have on the environment and human health. It is difficult to express why people should be concerned about the presence and use of these chemicals when there is not enough research completed that examines the risks, thus this research is greatly needed.

It would also be beneficial to increase the presence of CECs monitoring protocol in citizen science water quality programs throughout the world. Citizen science has been a valuable tool utilized in many scientific fields, and it would be beneficial to gain a better understanding of what chemicals are present in waterbodies through the implementation of citizen science.

Establishing citizen science CECs protocol would likely require a lot of work, including a lot of preliminary research to understand the best techniques and the best technology for citizen scientists to use, however it could be highly beneficial to researchers studying CECs, as well as citizen scientists, as they could gain precious knowledge and awareness of CECs through their research experiences.

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APPENDICES

APPENDIX A: ACRONYMS

ASWs	Artificial Sweeteners
CCL	Contaminant Candidate List
CECs	Chemicals of Emerging Concern
CSLAP	Citizen Science Lake Assessment Program
CWA	Clean Water Act
CyanoHABs	Cyanobacterial Harmful Algal Blooms
DBPs	Disinfection By-Products
EDCs	Endocrine Disrupting Compounds
EDSP	Endocrine Disruptor Screening Program
EPA	United States Environmental Protection Agency
FFDCA	Federal Food, Drug, and Cosmetic Act
NMs	Nanomaterials
NYSDEC	New York State Department of Environmental Conservation
NYSFOLA	New York State Federation of Lake Associations
PCPs	Personal Care Products
PFAS	Per- & Polyfluoroalkyl Substances
PFCs	Perfluorinated Compounds
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctane Sulfonate
PhACs	Pharmaceuticals
SDWA	Safe Drinking Water Act
TSCA	Toxic Substances Control Act
WWTPs	Wastewater Treatment Plants

APPENDIX B: DEMOGRAPHICS

Gender	**Female**	**Male**						
(N=40)	14	26						
	35%	65%						
Age	**18-20**	**21-29**	**30-39**	**40-49**	**50-59**	**60+**		
(N=41)	0	3	2	2	7	27		
	0%	7%	5%	5%	17%	66%		
Highest level of school completed	**Less than high school degree**	**High school degree of equivalent (GED)**	**Some college but no degree**	**Bachelor's degree**	**Graduate degree**			
(N=42)	0	2	3	15	22			
	0%	5%	7%	36%	52%			
Employment status	**Employed, working 40 hours or more per week**	**Employed, working 1 to 39 hours per week**	**Not employed, looking for work**	**Not employed, not looking for work**	**Retired**	**Unable to work**	**Other**	
(N=42)	8	8	1	0	24	0	1	
	19%	19%	2%	0%	57%	0%	2%	
Income per year	**Less than $10,000**	**$10,000 to $19,999**	**$20,000 to $34,000**	**$35,000 to $49,999**	**$50,000 to $74,999**	**$75,000 to $99,999**	**$100,000 to $149,000**	**$150,000 or more**
(N=34)	0	0	1	2	5	3	14	9
	0%	0%	3%	6%	15%	9%	41%	26%
Race-ethnicity	**White**	**Black or African American**	**Latino/a or Hispanic**	**American Indian or Alaskan Native**	**Native Hawaiian or Pacific Islander**	**Latino/a or Hispanic**		
(N=35)	35	0	0	0	0	0		
	100%	0%	0%	0%	0%	0%		

* The N for each of the categories varies somewhat because not all respondents answered all questions.

APPENDIX C: SURVEY INSTRUMENT

SUNY College of Environmental Science and Forestry

Syracuse University

Survey Regarding Chemicals of Emerging Concern in New York Lakes

Project Background: With increasing frequency countries and organizations are faced with chemicals that have not been considered as "contaminants" before. Some of these chemicals could pose risks to humans and/or the environment. These are the so-called **chemicals of emerging concern** (CECs). We are conducting a citizen science-based study to evaluate the occurrence of CECs in New York lakes that provide recreation services and serve as drinking water supplies. This survey is a first step for us to understand the public's perception about CECs. Results of this questionnaire will be treated anonymously. The survey will take approximately 15 minutes to complete. If you opt to write more, it may take longer. Thank you in advance for your participation.

Have you been working (with CSLAP) as a volunteer doing sampling and monitoring?

a. Yes
b. No

If not, please stop here: this survey is for people who have been conducting the sampling.

1. Have you ever heard the term, "chemicals of emerging concern" (CECs)?

   a. Yes
   b. No
   c. Not sure

2. Which of the following might be considered as CECs? Select one or more as you see fit.

   a. Arsenic
   b. Pesticides
   c. Lead
   d. Algal toxins
   e. Human-use pharmaceuticals
   f. Personal care products
   g. Animal-use drugs

3. Are you aware of any news stories or reports about the presence of CECs in New York state's waters (lakes, streams, etc.)?

   a. Yes
   b. No
   c. Not sure

4. What are the primary sources of CECs in natural water bodies? Select one or more as you see fit.

   a. Sewage treatment plants
   b. Septic systems
   c. Industrial and manufacturing facilities
   d. Residential households
   e. Crop fields
   f. Poultry farms and animal feeding facilities

5. Are there laws or policies regarding CECs in water, in New York state?
   a. Yes
   b. No
   c. Not sure

6. Are there laws or policies regarding CECs in water, in U.S. states other than New York?
   a. Yes
   b. No
   c. Not sure

7. Are you involved with a lake association?
   a. Yes
   b. No
   c. Not sure

If so, which one? ____________________

8. Do you have any questions regarding CECs (e.g., behavior, route of exposure, occurrence, toxicity, treatment technologies, etc.) or about this study? If yes, please list them below. We will do our best to respond in the next few weeks.

   a. Yes
   b. No

____
____
____
____
____
____
____

9. Do septic systems require regular maintenance?
   a. Yes
   b. No

If so, how frequently? ____________________

10. Have you heard the term 'straight pipe'?
   a. Yes
   b. No

If so, please explain: ____________________

____

SUNY College of Environmental Science and Forestry

Syracuse University

11. Below is a list of environmental problems. As you read each one, please note if you personally worry about this problem (circle one): **A** not at all **B** only a little **C** a fair amount **D** a great deal.

a) Pollution of drinking water	A	B	C	D
b) Pollution of rivers, lakes and reservoirs	A	B	C	D
c) Air pollution	A	B	C	D
d) Global warming and climate change	A	B	C	D
e) Extinction of plant and animal species	A	B	C	D

12. From your point of view, what is the main purpose of citizen science monitoring such as CSLAP (circle one)?

a) To generate data, of use to science (focused on scientific outcomes)
b) To achieve management outcomes (focused on supporting government)
c) To engage in a personal interest (focused on your own role)
d) To address environmental issues (focused on the ecosystem itself)

13. How much do you know about the following (circle one):
A not informed at all **B** not very informed **C** somewhat informed **D** very informed

a) Harmful algal blooms	A	B	C	D
b) Personal hygiene products	A	B	C	D
c) Invasive species	A	B	C	D
d) Microplastics	A	B	C	D
e) Volatile organic compounds	A	B	C	D
f) Pharmaceuticals	A	B	C	D
g) Endocrine disruptors	A	B	C	D
h) Agricultural runoff	A	B	C	D
i) Nutrient loading	A	B	C	D
j) Surface water runoff	A	B	C	D
k) Wastewater from homes/buildings	A	B	C	D

14. How many years have you been involved with CSLAP lake monitoring?

- ☐ 0-2
- ☐ 2-7
- ☐ 8-13
- ☐ 14-19
- ☐ 20 or more
- ☐ Other (explain)____

15. Are you a seasonal lake resident?

a. Yes
b. No

If so, is your main residence close by or not? (please explain)

____

____

16. Please think back to your decision to get involved with volunteer monitoring and CSLAP. What were your motivations (check **all** that apply)?

a. Have a personal interest in the topic of water quality
b. Desire to learn something new
c. Desire to discover something new
d. Desire to spend time in nature
e. Socializing with like-minded people
f. Desire to volunteer for a cause
g. Wish to contribute to science
h. Feel that it is important to help
i. Other ____

17. Have your reasons for participating in CSLAP changed over time?

a. Yes
b. No

If yes, how have they changed? In other words, please explain how your reasons for participating in CSLAP have changed over time.

____

____

SUNY College of Environmental Science and Forestry

Syracuse University

OPTIONAL: Demographics

Additional information is helpful in analysis. Please skip this section if you prefer not answer.

22. Which category includes your age?

- 18-20
- 21-29
- 30-39
- 40-49
- 50-59
- 60 or older

23. What is your gender? Male Female Other/prefer not answer

24. What is the highest level of school you have completed or the highest degree you have received?

- Less than high school degree
- High school degree or equivalent (GED)
- Some college but no degree
- Bachelor's degree
- Graduate degree

25. Which of the following categories best describes your employment status?

- Employed, working 40 hours or more per week
- Employed, working 1-39 hours per week
- Not employed, looking for work
- Not employed, not looking for work
- Retired
- Unable to work

Other (please specify)

26. How much total combined money did all members of your household earn in the previous year? This includes all forms of income and any money received by members of your household (do *not* subtract the amount paid in taxes or any deductions listed on your tax return)

- Less than $10,000
- $10,000 to $19,999
- $20,000 to $34,999
- $35,000 to $49,999
- $50,000 to $74,999
- $75,000 to $99,999
- $100,000 to $149,000
- $150,000 or more

27. What category (or categories) best match your race or ethnicity?

- White
- Black or African-American
- Latino/a or Hispanic
- American Indian or Alaskan Native
- Native Hawaiian or Pacific Islander
- Other (please specify)

APPENDIX D: SUMMARY OF COLLABORATIVE PROJECT

The survey utilized in this work was implemented as a portion of a collaborative project funded by the National Science Foundation (Award #1743988) involving environmental social scientists at SUNY-ESF, environmental engineers at Syracuse University, water quality professionals at Upstate Freshwater Institute in Syracuse, NY, and CSLAP volunteers and lake association members throughout New York State. The overarching goal of this project was to assess the feasibility of establishing an educational and training-based framework for citizen science research focused on CECs. This involved recruiting and training volunteer monitors for on-site CECs monitoring as well as evaluating the occurrence of CECs in New York lakes by analyzing water samples and data collected by volunteer monitors. Another goal of this project was to assess the levels of knowledge, awareness, and engagement of citizen scientists both before and after the CECs monitoring was completed. To assess these factors, both semi-structured interviews and a survey instrument were utilized. The survey instrument was designed as a pre- and post- survey, meaning that it would be completed by citizen scientists involved with this project both before and after their CECs monitoring experience, to determine the extent to which being trained in and performing CECs monitoring affected the knowledge, awareness, and engagement of these citizen monitors. Due to timing and funding limitations, this thesis is only focused on the pre-survey results and other members of the project are analyzing the pre- and post-survey comparison results.

APPENDIX E: WEBSITE INFORMATION

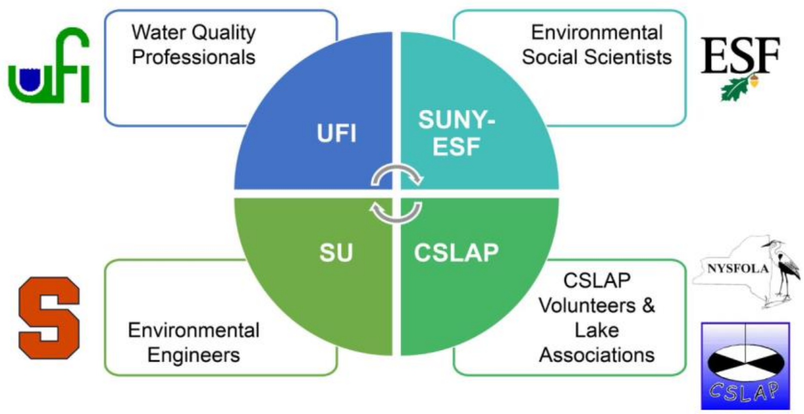
I created this website during the summers of 2018 and 2019 to inform the public of CECs and the collaborative NSF project as a whole. Please visit the website at http://monitoringcecs.org/.

Information about this Study

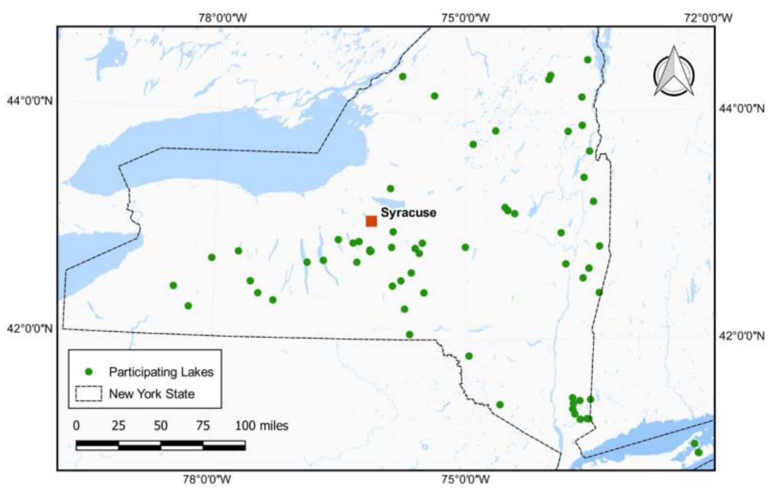
The long-term goal of this study is to help establish an adaptive, citizen-based CECs monitoring framework for improved lake watershed management. Professional researchers collaborated with citizen scientists from the Citizens Statewide Lake Assessment Program (CSLAP) in New York State to fill data gaps in CECs occurrence. This study also incorporated an assessment of knowledge acquisition and perceptions of citizen monitors by utilizing surveys and participant interviews.

Citizen monitors were recruited from local lake associations, trained to collect CECs data, and obtained water samples throughout the summer. As samples were submitted, researchers utilized several analytical platforms to evaluate the occurrence of CECs in New York State lakes. Final reports were created which document and interpret the findings of this study, both for CECs occurrence data as well as knowledge and perceptions of citizen monitors. Additional sampling is taking place during the summer of 2019.

Exploratory & Collaborative Study



Project Framework and Timeline



Distribution of Participating Lakes

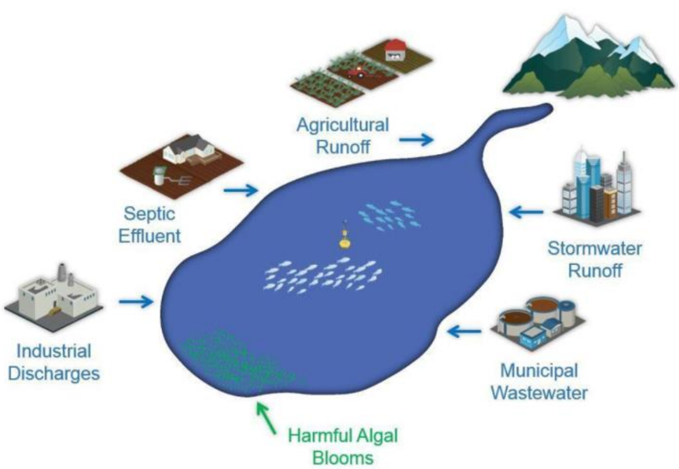
A specific group of lakes were chosen to participate in this study. The basis for selection included a variety of watershed characteristics (e.g., land use patterns, watershed-to-lake ration), lake morphological features (e.g., mean depth, surface area, shoreline length), water quality trends (e.g., chlorophyll – levels, history of harmful algal bloom events), and geographic locations.

What are chemicals of emerging concern (CECs) and why are they concerning?

Chemicals of emerging concern (CECs) comprise a wide array of synthetic (i.e., man-made) and naturally occurring organic compounds that are found with increasing frequency at low levels in the aquatic environment. They are thought to potentially have adverse impacts on ecological function via endocrine disruption and/or cause antibiotic resistance. Some may also negatively impact human health.

Also, while some CECs are resistant to natural environmental degradation processes, others have the ability to undergo transformations, occasionally forming secondary products that are more problematic.

Category	Examples
Human-use pharmaceuticals	Prescription and over-the-counter drugs, illicit drugs
Personal care products	Sunscreen ingredients, antimicrobial agents, plasticizers
Household chemicals	Surfactants, flame retardants
Food additives	Artificial sweeteners, stimulants
Agricultural pesticides	Herbicides, insecticides, fungicides
Veterinary drugs	Hormonal growth promoters, anti-parasitic agents
Industrial chemicals	Perfluorinated compounds, corrosion inhibitors
Algal toxins	Microcystins, anatoxins, cylindrospermopsins



How do CECs enter lakes and other bodies of water?

CECs can end up in different waterbodies through numerous avenues. Some of the major sources of CECs are illustrated to the left. With the development of new and innovative technology, researchers are able to test and analyze very small quantities of chemicals.

Through use of this technology, it is possible to measure many different chemicals, including cyanotoxins, which can be produced by harmful algal blooms (HABs).

What CECs are monitored in this study?

The four primary CECs we chose to focus on in this study are microcystins, atrazine, caffeine, and sucralose.

In addition, we looked for the presence of other previously detected or expected CECs including antimicrobial agents, over-the- counter medications, and chemicals found in household cleaning products.

Sucralose: An artificial sweetener found in treated sewage, discharged from septic systems or sewage treatment plants

Atrazine: A widely-used herbicide found in agricultural runoff

Caffeine: A stimulant found in raw sewage or combined sewer overflows

Microcystins: A group of algal toxins produced by harmful algal blooms (HABs)

On-Site Strip Tests for CECs

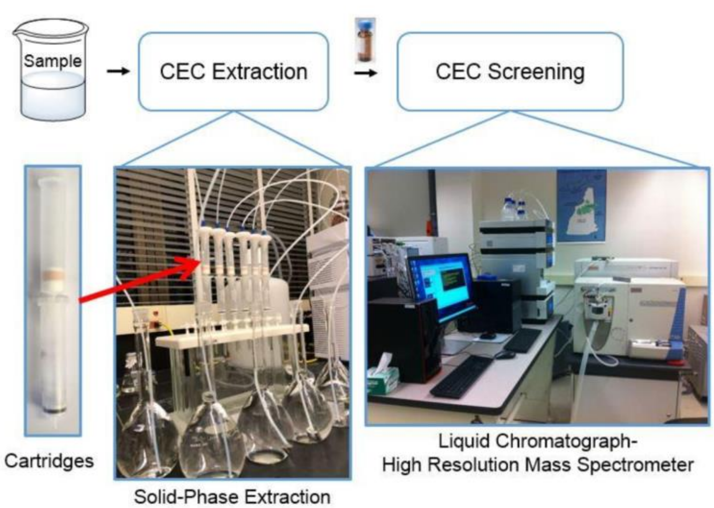
Strip tests were utilized by citizen scientists to monitor levels of microcystins and atrazine in lakes

1. Strip tests gave a high false-positive rate on microcystins occurrence.
   - Integrity of test strips may have been compromised by storage conditions
   - Interpretation of strip test results is confounded by uncertainty in integrity of the strips

2. Strip tests provided qualitative information on the absence of atrazine, but were not sufficiently sensitive to detect ng/L levels of atrazine in the lakes.

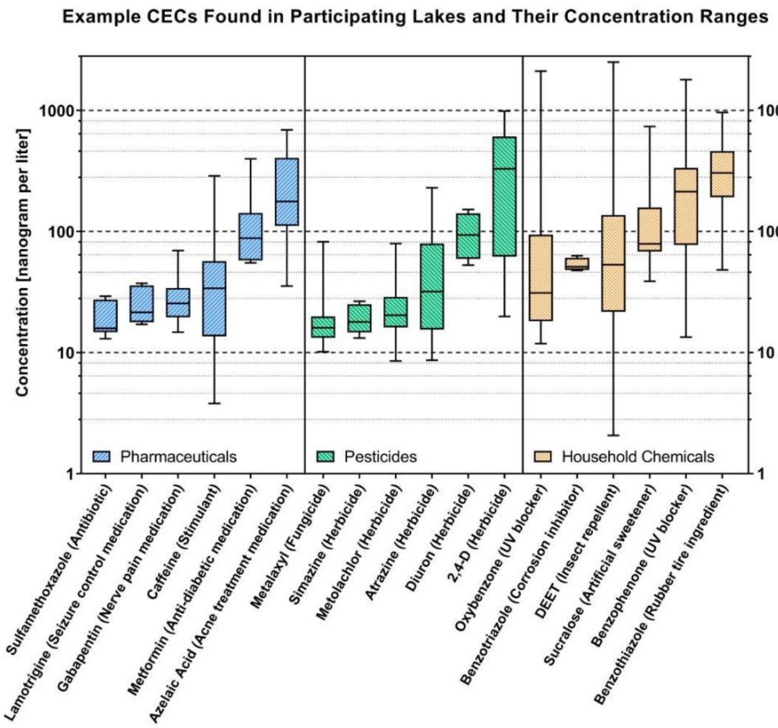
3. On-site monitoring of microcystins and atrazine using strip tests should be followed up with more rigorous laboratory tests, as was done in this study.

CECs Analysis: Screening for 217 Compounds



CECs Results

Concentration profiles of CECs (Middle line = Median; Whiskers = Minimum to Maximum)



SUNY College of Environmental Science and Forestry
Syracuse University

ESF

Survey Regarding Chemicals of Emerging Concern in New York Lakes

Project Background: With increasing frequency countries and organizations are faced with chemicals that have not been considered as "contaminants" before. Some of these chemicals could pose risks to humans and/or the environment. These are the so-called **chemicals of emerging concern** (CECs). We are conducting a citizen science-based study to evaluate the occurrence of CECs in New York lakes that provide recreation services and serve as drinking water supplies. This survey is a first step for us to understand the public's perception about CECs. Results of this questionnaire will be treated anonymously. The survey will take approximately 15 minutes to complete. If you opt to write more, it may take longer. Thank you in advance for your participation.

Have you been working (with CSLAP) as a volunteer doing sampling and monitoring?
a. Yes
b. No

If not, please stop here: this survey is for people who have been conducting the sampling.

1. Have you ever heard the term, "chemicals of emerging concern" (CECs)?
   a. Yes
   b. No
   c. Not sure

2. Which of the following might be considered as CECs? Select one or more as you see fit.
   a. Arsenic
   b. Pesticides
   c. Lead
   d. Algal toxins
   e. Human-use pharmaceuticals
   f. Personal care products
   g. Animal-use drugs

3. Are you aware of any news stories or reports about the presence of CECs in New York state's waters (lakes, streams, etc.)?
   a. Yes
   b. No
   c. Not sure

4. What are the primary sources of CECs in natural water bodies? Select one or more as you see fit.
   a. Sewage treatment plants
   b. Septic systems
   c. Industrial and manufacturing facilities
   d. Residential households
   e. Crop fields
   f. Poultry farms and animal feeding facilities

Civil and Environmental Engineering | 151 Link Hall | Syracuse, NY 13244

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Purpose of Surveys and Interviews

1. To understand the level of knowledge held by CSLAP volunteers about CECs.

2. To document the impact of training and monitoring relative to knowledge, awareness, and engagement through use of pre- and post-sampling surveys.

Survey and Interview Results

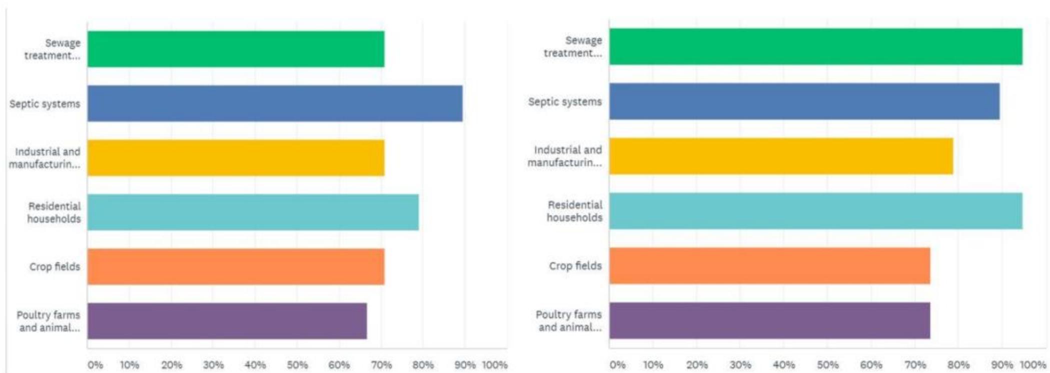
Volunteers doing lake monitoring have fairly high levels of knowledge about factors affecting watershed health and lake dynamics.

Some volunteers mentioned interest in additional attention toward wastewater sources, such a septic systems, entering lake watersheds.

Volunteers who participated in training and strip testing demonstrated higher levels of knowledge and awareness about contamination, specifically in connection with wastewater as a source of pollutants for their lake.

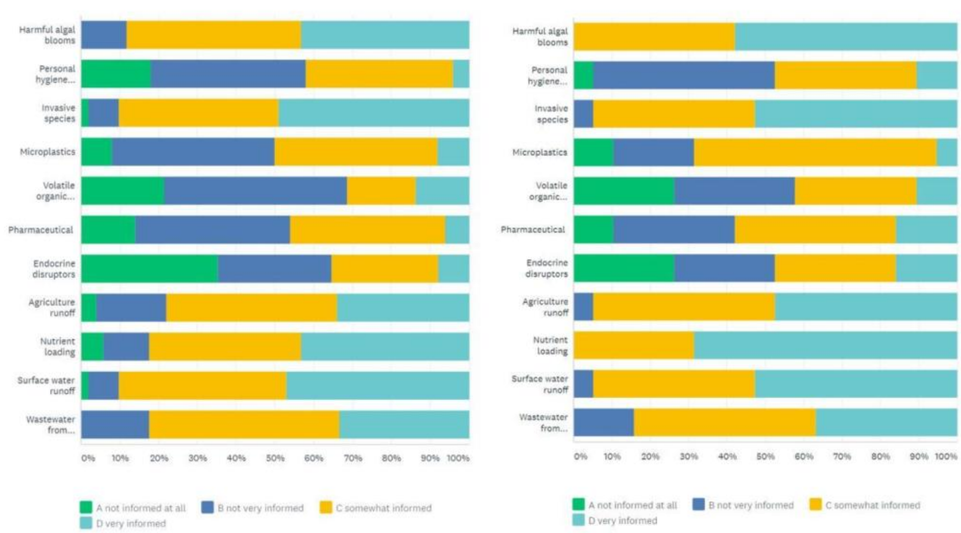
Knowledge of CECs Contamination Sources

(left = pre-survey; right = post-survey)



Knowledge of Factors Affecting Water Quality

(left = pre-survey; right = post-survey)



Contact Information



General Information	Monitoring Information	Survey Information
Teng Zeng	MaryGail Perkins	Sharon Moran
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Updates and News

June 2019 - Additional followup sampling begins

December 2018 - Study results available on the NYSFOLA website, linked below

October 2018 - Sampling wraps up

June 2018 - Sampling begins

» NYSFOLA » NYSDEC

CURRICULUM VITAE

Katherine M. Fee

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Education

Master of Science, Coupled Human and Natural Systems CGPA 3.89
State College of New York College of Environmental Science and Forestry. Syracuse, NY
Expected: December 2019

Bachelor of Science, Environmental and Ecosystem Sciences; Minor, Geology CGPA 3.82
Washington State University. Pullman, WA
May 2017

Professional Experience

Senior Research Aide May 2019 – July 2019
SUNY - College of Environmental Science and Forestry Syracuse, NY

- Finalized and published an informative website utilizing DreamHost software that educates the public on chemicals of emerging concern (CECs) and citizen science as an extension of master's thesis research (http://www.monitoringcecs.org/)

Graduate Teaching Assistant Aug 2017 – Jan 2019
SUNY - College of Environmental Science and Forestry Syracuse, NY

- Geospatial Information Technologies (Jan 2018 – Jan 2019)
    - Honed expertise of Geographic Information Systems through back-to-back semesters of teaching ~90 students ArcMap 10.1 and extensions in a computer lab setting
    - Demonstrated effective teaching strategies and solutions to fellow teaching assistants
    - Completed grading in a timely manner and held highly attended office hours
- History of the American Environmental Movement (Aug 2017 – Jan 2018)
    - Participated in College-Wide Colloquium on Teaching to refine instructional skill set
    - Graded research papers, assisted with class lectures, held office hours

Graduate Research Assistant May 2018 – Aug 2018
SUNY - College of Environmental Science and Forestry Syracuse, NY

- Co-developed a 27 question survey regarding the knowledge and perceptions of individuals involved with volunteer water quality monitoring on the topic of chemicals of emerging concern (CECs) as well as their motivations for participating in volunteer monitoring
- Drafted a website for CECs and citizen science information dissemination

- Collected and analyzed survey data gathered from 55 citizen scientists
- Adapted and simplified pre-designed strip test protocols for citizen scientists collecting water quality data on microcystins and atrazine

Sustainability Student Coordinator June 2016 – May 2017
Washington State University, Environmental Health and Safety Pullman, WA

- Collaborated with a multidisciplinary team of Environmental Health and Safety staff to plan and run a campus sustainability fair both for and involving students, faculty, staff, and vendors
- Completed an investigative research project regarding sustainability programs of schools within the Pac-12 Conference

Intramural Supervisor Jan 2016 – Oct 2016
Washington State University Recreation Pullman, WA

- Supervised intramural sports and a variety of sports club team practices and events
- Aided in skill development of officials through verbal and written evaluations completed approximately 3 times per month
- Handled conflict, enforced policy, and ensured safety of participants

Cougar Kids Camp Coordinator May 2016 – Aug 2016
Washington State University Recreation Pullman, WA

- Directed a summer youth camp for children grades 1-6 with an average attendance of 110 children per day and a staff of 15 college students
- Planned and supervised daily camp activities and events including pick-up and drop-off of children, games, excursions, swimming sessions, and special events
- Communicated consistently and effectively with parents, staff, and other coordinators
- Handled conflict and emergencies in an appropriate and professional manner

Student Intern Aug 2014 – May 2015
Division of Governmental Studies and Services (DGSS) Pullman, WA

- Inputted survey responses to SPSS software from a community needs survey
- Aided in coordinating a fundraising event for the SR-530 mudslide recovery in Oso, WA

Natural Resources Intern June 2014 – Aug 2014
Washington State University, Snohomish County Extension Darrington, WA

- Selected as one of twelve students to indirectly aid in the recovery effort of the SR-530 mudslide in Oso, WA
- Organized a paid summer employment program for 12 high school students focused on leadership development and environmental education of topics such as forestry, wildlife biology, conservation, sustainability, etc.
- Supported fellow interns with K-6 robotics and nutrition programs

Research and Field Experience

- Master’s thesis research - Citizen Science Lake Monitoring: Exploring CECs Monitoring in New York State
- Association for the Advancement of Sustainability in Higher Education (AASHE) Conference attendee, 2016
- Volunteer research in forest ecosystems program: Old Growth Forests of Yosemite, 2016
- Montana research excursion with focus on sexual selection in mule deer, 2016

Leadership and Involvement

- Teaching Fellow: College-Wide Colloquium on Teaching and Learning, 2018
- ASWSU Environmental Sustainability Alliance Co-Chair, 2016-2017
- Sustainability and Environment Presidential Committee Member, 2016-2017
- Chi Omega Beta Beta Fraternity Member, 2015-2017
- Chi Omega Beta Beta Alumni Relations Chair, 2016-2017
- Committee Squared Registered Student Organization Member, 2016-2017
- Environmental Science Club Secretary, 2015-2016

Honors and Awards

- W Nelson and M McLeod Scholarship, 2016-2017
- McCroskey Endowment Fund Scholarship, 2015-2016 & 2016-2017
- Chi Omega Academic Excellence Award, 2016
- Junior Writing Portfolio: Pass with Distinction, 2016
- Roberts Carl Schmidt Scholarship, 2015-2016
- Arthur F. Noskowiak Scholarship, 2015-2016
- Harold Nyberg Endowment Scholarship, 2015-2016
- Rockie Family Scholarship, 2014-2015 & 2015-2016
- Washington State University Academic Achievement Award, 2013-2015
- Educational Foundation Scholarship, 2013-2014
- President’s Honor Roll Recipient, Fall 2013-Spring 2017